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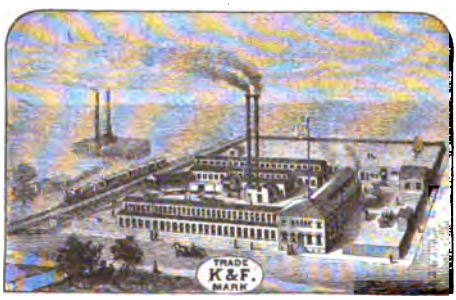

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SPRING-POLE DRILLING.

BY EDGAR G. TUTTLE, '81.

THE spring-pole drilling outfit here described, is one that can be used with advantage in making explorations where drilling to a depth of about 200 or 250 feet or less is required.

It is suitable for determining, within these limits, the depth and thickness of coal-beds, stratified rocks, ore-deposits, etc. It can also be used in drilling for water.

Spring-pole drilling has, to a great extent, been displaced by horse-power, steam and diamond drilling machines: but where a few holes are to be drilled, or at shallow depths, and speed is not of importance, spring-pole drilling has manifest advantages over other methods, on account of its moderate first cost, the readiness with which it can be moved from one location to another, its few requirements, and, consequently, small cost of operation and maintenance.

Especially is this method of advantage in countries where water is scarce and feed for horse-power or fuel for steam or diamond drilling are not readily obtainable.

For explorations at greater depths than 200 or 250 feet a horse-power, steam or diamond drill is necessary.

A horse-power drill is suitable for moderate speed and depths, a steam drill for greater speed and depth, and if the explorations are very extensive and deep, and speed is an object, the expense of a diamond drill will be warranted.

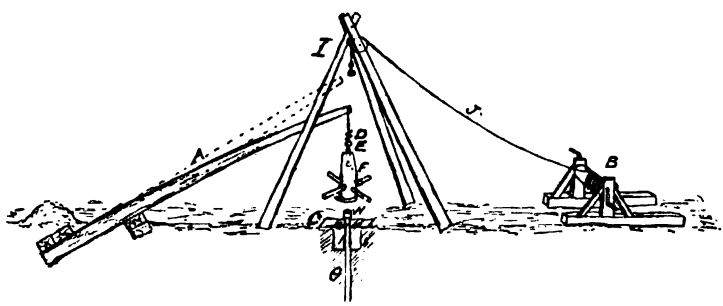
If a core-drilling is necessary, the use of a diamond drill is at once determined.

In these cases special arrangements may be necessary for obtaining the necessary feed for a horse-power drill, and fuel and water for a steam or diamond drill, especially in dry or barren countries. If these are to be hauled, teams and wagons will be required for hauling the machinery from one location to another and hauling fuel and water.

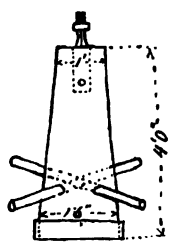
About one-half to one ton of coal, or its equivalent in other fuel, and 1000 to 2000 gallons of water may be needed daily with the latter outfits, and these items may considerably increase the cost of drilling by steam, etc., as compared with the spring pole.

The accompanying illustrations show the detailed construction of the special tools for spring-pole drilling. They can be made in

FIG. 1.



Hitch Knot (D).



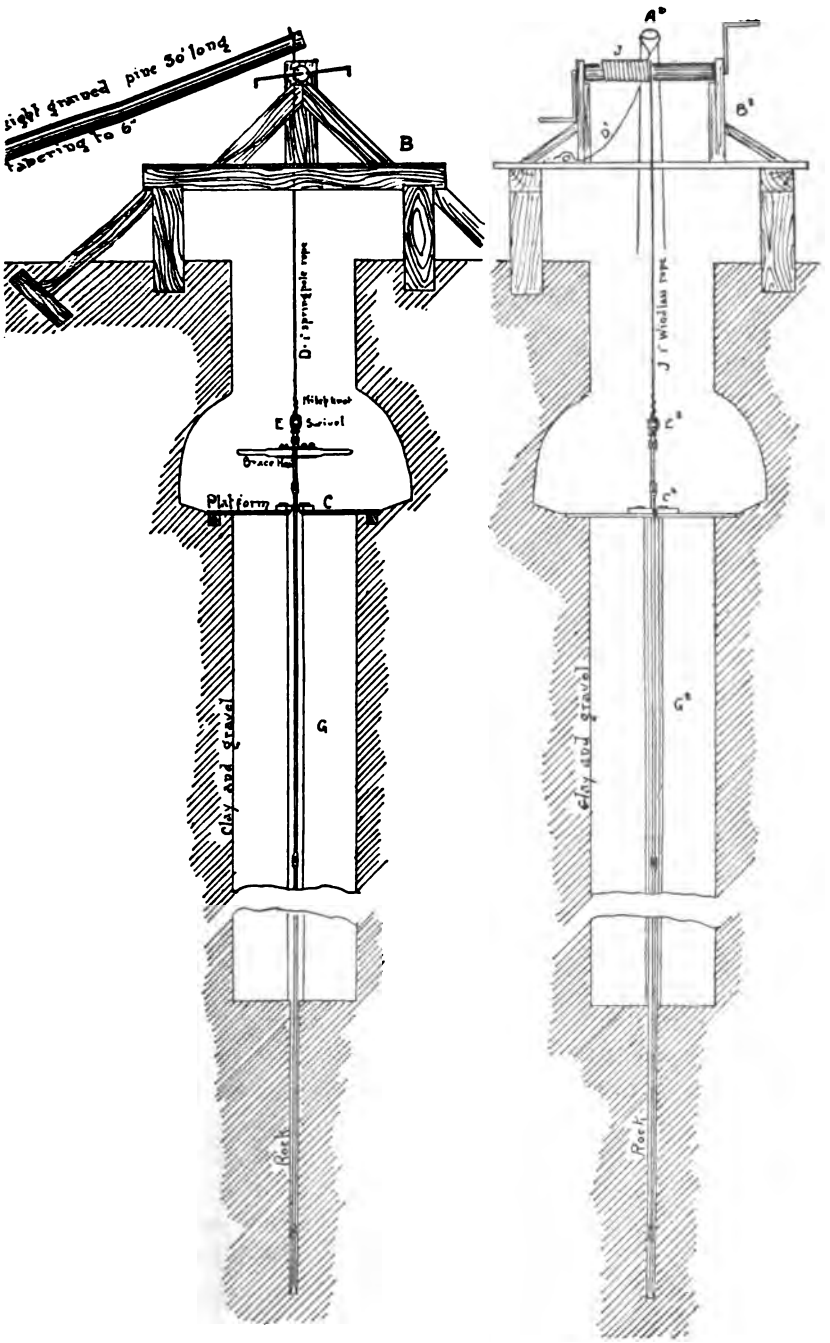
Pipe Driver (F).

Splicing Iron (K).

any blacksmith shop, and repairs, sharpening, etc., can be kept up in the field with a portable forge, if this is accessible.

Fig. 1 shows the spring-pole outfit erected entirely above ground

FIG. 2.


Light grooved pipe 50 long
tapering to 6"
B
Jars and Bucket
Hickory boot
E
Swivel
Brace
Platform
C
G
Clay and gravel
Rock
A'
J
B'
C'
G'
Clay and gravel
Rock

and fitted up for pipe driving and earth boring and, subsequently, drilling.

This arrangement is adopted, 1st, where earth boring and driving of pipe for casing to the rock are necessary either on account of the soil being wet or caving, or on account of the soil being of considerable depth, or where it can be bored and cased cheaper than it can be excavated by shafting. 2d. Or the same arrangement is used where the rock strata begin at the surface and rock drilling from the start is necessary. In this case the pipe driver and piping are replaced by the rock-drilling arrangements as shown in Fig. 2.

Fig. 2 shows the arrangement of the spring-pole outfit, with working platform below the surface, and in a special case where it

View of Spring-Pole Outfit Erected as Shown in Fig. 2.

was cheaper to sink a shaft 4 feet square through dry, tenacious soil 45 feet deep to the rock, than to bore and drive casing pipe.

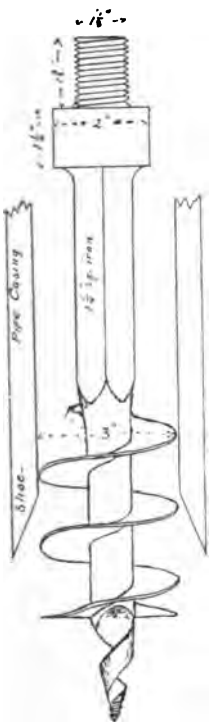
The arrangement of the platform below ground, as in Fig. 2, has the advantage over the arrangement shown in Fig. 1 in that the outfit is more compact and accessible. The spring pole need not be erected with its end as high above the ground and the derrick is not needed.

Even if earth boring and driving of pipe casing are necessary for considerable depth, where a pit 12 feet deep can be excavated and a platform erected 8 feet below the surface, as shown in Fig. 2, such an arrangement is best. The earth-boring and pipe-driving tools can then be used from this point downwards to the rock. The pipe driver shown in Fig. 1 can likewise be used in the arrangement shown in Fig. 2, by attaching it to the swivel of the

spring-pole rope in the place of the drill rods, which are shown in position, ready for operating, in Fig. 2.

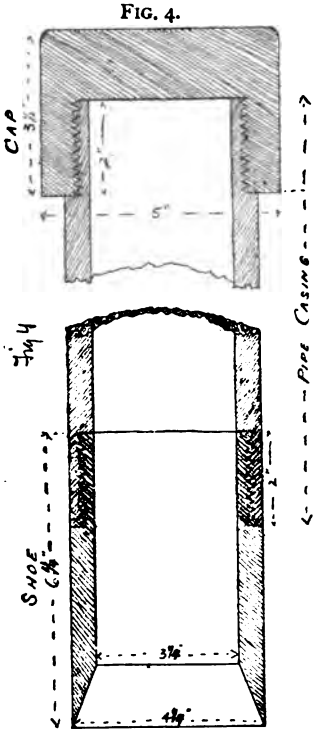
Where gravel or boulders are present in the soil above the rock, it may be necessary to sink a shaft to the rock, as shown in Fig. 2, and erect either a wooden or pipe casing to the working platform, to prevent dirt and water, with drillings, from falling into the drill hole.

FIG. 3.



Earth Auger.

FIG. 4.

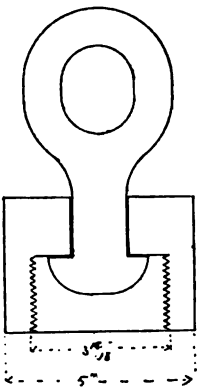


Pipe Casing, Cap and Shoe.

Figs. 3, 4 and 5 show the special earth-boring and pipe-driving tools used in connection with the arrangement shown in Fig. 1 and the drill rods shown in Fig. 6, which are also used for attaching to the earth-auger in boring.

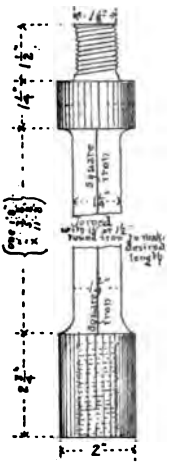
Fig. 4 shows a section of the pipe fitted up with a shoe and a cap ready for driving. The shoe is bevelled and pointed, so as to facilitate its wedging into the soil from the blows delivered on the cap by the pipe driver. The pipe lift, Fig. 5, is used for removing

FIG. 5.



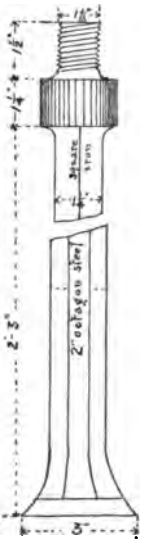
Pipe Lift.

FIG. 6.



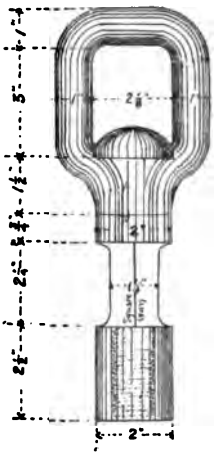
Drill Rod.

FIG. 7.



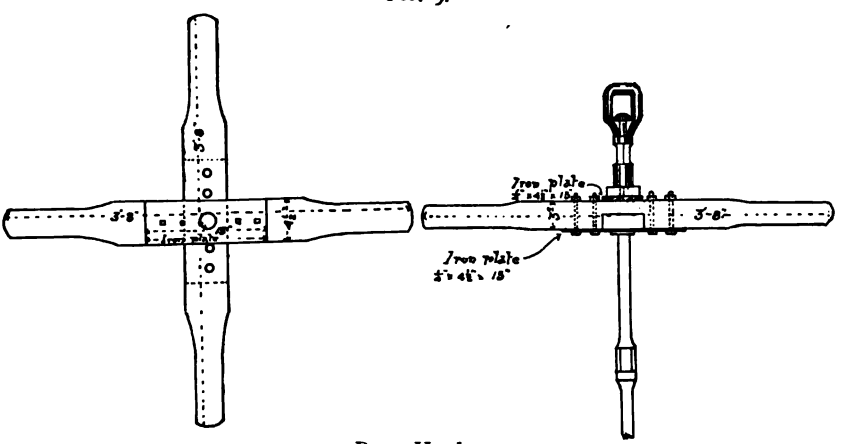
Drill Bit.

FIG. 8.



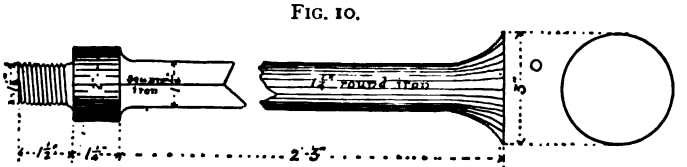
Swivel.

FIG. 9.



Brace Head.

FIG. 10.



Reamer.

the pipe from a hole. It is screwed on to the end of the pipe, being interchangeable with the cap, and by means of the rope and windlass it is lifted, assisted with screw jacks if the pipe is tight in the soil or of considerable depth.

Figs. 6 to 16 inclusive show the special rock-drilling tools. The drills, rods, swivels, reamer, fishing tools, heavy sand pump, pipe driver (Fig. 4) and the earth augur (Fig. 3) are fitted with connecting screw ends, as shown, which are 1⅛ inches diameter to outside of threads and 8 threads to the inch.

The accompanying list of tools gives the complete outfit needed:

List of Tools and Equipment.

Reference.

Figs. 1, 2, A. 1 round pine spring pole, 30 feet long, 6 inches and 10 inches diameter.
" " B. 1 windlass, with supports.
Fig. 1, I. 1 derrick, with pulley.
Figs. 1, 2, C. 1 platform for foot wrench.
" " D. 50 feet of 1-inch Manilla rope for support of rods or pipe driver to spring pole.
" " J. 50 feet of 1-inch Manilla rope for lifting rods or pipe with windlass.
250 feet of ½-inch Manilla rope for sand pump.
" " K. 1 splicing iron 10 inches long.

Boring and Pipe-Driving Tools.

Fig. 1, F. 1 pipe driver, oak, 4 feet long, 12 inches and 18 inches diameter, iron bound.
Fig. 3, 1 3-inch earth auger, with same rods and brace head as used for drilling in Figs. 6 and 9.
Fig. 4, 1 driving cap.
1 driving pipe 1 foot 2 inches long.
1 " " 2 feet 2 " "
1 " " 3 " 2 " "
1 " " 4 " 2 " "
1 " " 5 " 2 " "
33 " pipes 6 " 2 " " for 200 feet of casing.
1 shoe 6¼ inches long.
Fig. 5, 1 pipe lift.
1 chain wrench for pipe and cap 4¼ and 5 inches outside diameter.
1 alligator " " " " " "
Fig. 18, 2 screw jacks for loosening casing.
2 clamps for holding and raising pipe with jacks.

Rock-Drilling Tools.

Fig. 6, 1 rod 1 foot 8 inches between shoulders, } Made of 1¼-inch or 1½-inch round iron, with ends near joints of 1¼ inches square iron for holding with wrench.
1 " 3 feet 8 " " "
1 " 5 " 8 " " "
16 rods 11 feet 8 inches between shoulders, for 200 foot hole.

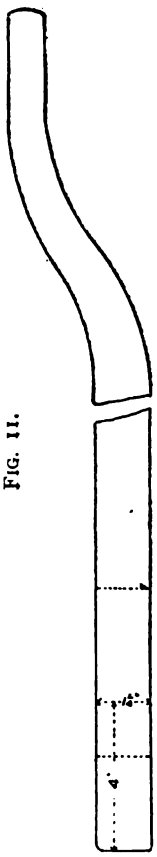


FIG. 11.

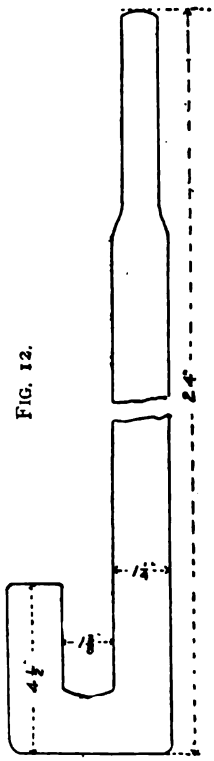


FIG. 12.

FIG. 13.

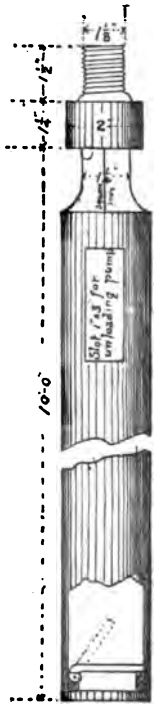


FIG. 14.

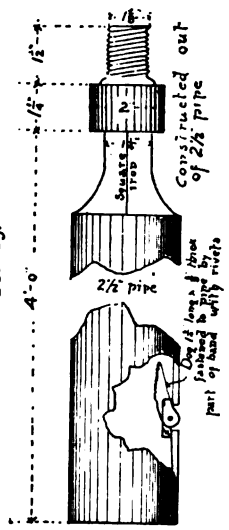


FIG. 15.

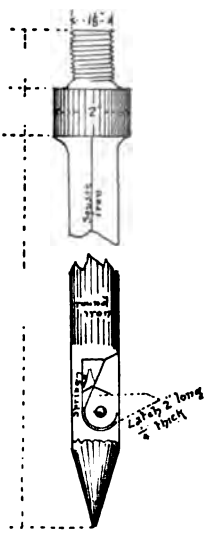


FIG. 16.

Fig. 11.—Foot Wrench.
Fig. 12.—Hand Wrench.
Fig. 13.—Sand Pump for Light Drillings.
Fig. 14.—Sand Pump for Heavy Drillings.
Fig. 15.—Grab for Drills and Rods.
Fig. 16.—Grab for Sand Pump.

Fig. 7, 6 drills, with 3-inch steel bit, made of 2-inch octagon steel.
Fig. 8, 2 swivels, one attached to windlass rope and one to spring-pole rope.
Fig. 9, 1 brace head for operating drill and rods.
Fig. 10, 1 reamer for truing hole.
Fig. 11, 1 foot wrench for holding rods on platform.
Fig. 12, 1 hand or disconnecting wrench.
Fig. 13, 1 sand pump for light drillings.
Fig. 14, 1 " " coarse or pasty drillings.
Fig. 15, 1 fishing tool—Grab for drills and rods.
Fig. 16, 1 " " sand pump.
2 barrels or kegs for holding water.
black oil for rod and pipe joints.

In addition to above are needed one small kit of blacksmith's tools, anvil and forge for sharpening and repairing. A few machinist's tools for pipe-fitting and threading, and carpenter tools for erecting windlass and platforms.

Erecting the Spring Pole, Platform, Etc.

The spring pole is erected as shown in Figs. 1 and 2 with its upper end nearly over the location for the hole, or that part from where the rope suspends about 2 or 3 inches back of the line of the hole, so that when the weight of the rods comes on the spring-pole in drilling, this point will come over the hole or travel ½ inch to 1 inch from one side to the other of the hole when being operated.

There should be sufficient height between the upper end of the spring pole and the working platform to operate the pipe driver in sinking pipe or the brace head in drilling.

The pulley of the derrick in Fig. 1 or the windlass reel in Fig. 2 is erected 13 feet or more above the working platform so as to have enough height for handling the longest pipes and rods in raising and lowering them.

If the platform is arranged as shown in Fig. 2 a distance of 8 feet below the surface is sufficient.

In order to handle the pipe in driving, it is necessary to have access to it for 3 or 4 feet below the platform level, so that if the outfit is all erected above ground as in Fig. 1, it will be necessary to sink a pit centrally on the location of the hole and 3 or 4 feet deep below the working platform (C) or else erect the working platform 3 or 4 feet above the level of the ground and raise the end of the spring pole and windlass reel or pulley a like amount. The

platform has a central removable blocking with a hole large enough to introduce the piping and rods.

The method of operating the spring pole is as follows:

Driving Through Soil or Loose Material.

The pipe driver is placed in position as shown in Fig. 1 for operating above ground. The screw end of the upper part of the pipe driver being screwed into the end of the swivel attached to the spring pole rope. If the pipe driver is to be operated below ground, as in Fig. 2, the connection with the spring-pole rope would be the same, the brace head shown in Fig. 2 being removed and replaced by the pipe driver.

A six foot length of pipe is fitted with a cap and shoe as shown in Fig. 4 and placed in position for driving. The lower end is sunk some distance in the ground by hand. The upper end is guided by the platform blocks, while the lower end is sunk into the soil by the blows of the pipe driver delivered upon the upper end. In driving not more than three feet of the pipe extends above the platform, more than this necessitates the pipe driver being too high for ease in operation. About 1½ to 2½ feet above the platform is better.

The pipe driver is adjusted by the rope of the spring pole being raised or lowered as needed and held in place by a hitch knot in the rope at the swivel end.

In starting to drive the pipe, the pipe driver is fastened by a hitch knot so that its lower end will nearly rest on the cap of the pipe.

Two or four men standing between the handles of the pipe driver, and each with a hand on a different handle, then raise and lower the pipe driver by means of the handles and assisted by the spring of the pole, they let it strike the cap of the pipe squarely on its down blow. After the pipe has been driven 4 or 6 inches, the men at the handles instead of exerting more force on the up stroke find that it is necessary to apply more strength on the down stroke and less on the up stroke as the spring pole assists in lifting the pipe driver. After driving 6 or 8 inches the hitch knot is then loosened by a splicing iron and the driver lowered within an inch or so of the cap, the knot tightened and the driving repeated as in the beginning of the operation, until the pipe has been driven down about 2 feet, or so that about 6 inches remain above the plat-

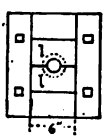
form. Then the cap is removed and a 1-foot length of pipe added with the cap screwed on top. This is similarly driven down until 4 or 6 inches of the pipe remain above the platform, or enough so that the pipe and cap can be grasped by wrenches to permit of uncoupling.

The cap and the 1-foot length of pipe are now removed and a 2-foot length added with the cap screwed on top. This is again driven down until about 6 inches of the pipe remain above the platform when the cap and 2-foot length of pipe is removed and similarly, a 3-, 4-, 5- and 6-foot length are in turn put in place, the 6 foot length remaining connected with the first 6-foot length and shoe and driven in the ground to form the second length of the casing. The driving with the 1-, 2-, 3-, 4-, 5- and 6-foot lengths of pipe is then repeated, the 6-foot length remaining in place each time and being driven in the soil to form a part of the casing. The operation continues until rock is reached.

If the soil yields readily so that the pipe drives easily, the 2-, 4-, and 6-foot lengths need only be used, which makes the pipe stand higher above the platform in driving, but reduces the time of changing lengths and cap and increases the speed of driving.

To facilitate the joining of the lengths of pipe in these frequent changes, the opening in the platform C is arranged so as to be readily opened and closed by the loose blocking as shown at *l* in Fig. 17. The joining of the successive rods is required to be done below the platform.

FIG. 17.



Platform set.

The joints of the pipes are oiled to permit of their being easily disconnected. If the soil has not sufficient resistance to hold the lower pipes in place while disconnecting the upper pipe with a wrench, then it will be necessary to make a small platform around the pipe, 4 feet below the platform C (Figs. 1 and 2) on which to grasp the lower pipe with a chain or alligator wrench while disconnecting the upper pipe.

The play of the spring pole varies from 6 to 14 inches, depend-

ing greatly upon its stiffness and the weight of the pipe driver. The weight of the pipe driver will vary from 200 to 600 pounds, depending upon the depth of piping to be driven. The best arrangement is to have a pipe driver weighing 200 or 300 pounds, whose weight can be increased as desired by adding bands or ribs of bar iron.

Boring Through Soil or Loose Material.

After driving the pipe until it ceases to sink in the soil or nearly so, which distance may vary from a few inches to several feet, the pipe driver is removed and the cap and such length of pipe is removed as is necessary to reduce it to about the level of the platform. The earth auger (Fig. 3), is then connected with the desired length of drill rods (Fig. 6) and lowered inside the piping by means of the windlass rope and swivel (see J in Figs. 1 and 2). When the auger rests on the soil in the pipe, the rods should be of such length, that, when the brace-head (Fig. 9) is connected to the top of the rods, it will not stand over 3 or 3½ feet above the platform, so as to facilitate the boring.

Men now turn the brace-head around by pushing on the handles as they walk around the hole, thus imparting a boring movement to the rods and auger. The auger is thus sunk as far as the strength of the men and rods and resistance to the auger will permit. The brace-head is then removed and the rods and auger, with its load of earth, are lifted by the windlass. The operation of lowering and raising the rods, connecting and disconnecting, is described further on under "Drilling."

The auger and rods are again returned into the hole through the piping, and the operation of boring and removing soil is repeated as often as is necessary to penetrate the soil as far as the piping has been driven and such distance ahead of the piping as the nature of the soil will permit. Fig. 3 shows the auger penetrating some distance in advance of the piping.

Even if the soil is slightly caving, it assists the driving of the pipe to remove some of the soil in advance of it with the auger.

Depending upon the nature of the soil, the auger is sunk a few inches to several feet between the operations of driving the pipe. Generally 1 to 3 feet can be driven in ordinary sandy and clayey soils. In some firmer and more tenacious soils a greater distance can be driven. In loose, sandy soil and gravel it will only be possible to sink a few inches at a time ahead of the pipe.

The operations of driving and boring are repeated until the piping is sunk to rock. Then the hole is cleaned and the pipe, driver and cap are removed. Such lengths of casing-pipe are removed or added as will bring the top of the pipe just below the platform, not more than a foot, so as not to interfere with the following operation of handling the rods and wrenches in drilling.

Lowering the Drill Rods.

If a shaft is excavated through the soil to the rock a wooden box can be constructed for a casing from the rock to the platform, as shown in Fig. 2, instead of using the piping for the rods to work in.

In either case, or assuming that the hole has been drilled some depth from the surface or from the bottom of the casing, the operation of lowering the rods is as follows:

A drill-bit, Fig. 7, is fastened to a drill-rod, Fig. 6, then tightened with the wrenches, Figs. 11 and 12, and lowered in the hole in the centre of the platform, C, and through the casing or into the drill hole. The longer rods are used firstly, such as the depth will permit.

The top of the drill-rod is held at the squared part of its shoulder by the foot-wrench, Fig. 11, on the platform, while another rod is coupled to it and tightened by means of the hand-wrench, Fig. 12. The swivel of the windlass rope is screwed to the top of the rod and the whole length of rods is lifted by the windlass a few inches. The weight thus being relieved from the foot-wrench, it is removed and the rods are lowered until the upper end is near the platform. The foot-wrench is again similarly placed around the squared end of the rod and the whole weight of rods allowed to hang from it as it rests on the platform. The swivel of windlass rope is removed and lifted, and other rods are likewise jointed and lowered by the windlass.

On nearing the bottom of the casing or hole, such lengths of the 6-, 4- and 2-foot rods are used as will leave about 2 or 3 feet above the platform when the bit is resting on the rock. The windlass rope and swivel are then removed, and the brace-head, with its swivel, is screwed upon the drill-rod. The entire length of rods is slightly raised and the end of the spring-pole rope is passed through the swivel and tied by a hitch knot. The rods are then

allowed to suspend from the spring-pole and are in readiness for the operation of drilling.

Each joint of the rods is oiled as connection is made, so as to permit of readily uncoupling them when they are lifted.

Drilling.

If the rock-drilling begins at the surface, a hole is first drilled as deep as possible by hand. A drill-bit, Fig. 7, with required length of drill-rods, Fig. 6, are then lowered through the hole in the centre of the platform, C, into the drill-hole. The lower end of the brace-head, Fig. 9, is then connected to the top of the drill-rods and the swivel of the spring-pole rope is secured to the top of the brace-head.

By means of a hook on the windlass-rope or by the two or four men, the brace-head and the length of rods are lifted 2 or 12 inches, depending upon the weight of the rods, and then the lower end of the spring-pole rope is passed through the swivel of the brace-head, tightened and tied in a hitch knot. The weight of the rods is thus allowed to suspend from the spring-pole rope, with the drill-bit an inch or so above the rock, so that by the up and down strokes given by the two or four men at the handles of the brace-head, the bit will come with sufficient force against the rock to deliver a cutting blow on the rock.

Four men operate the drill on heavy work, two men on light work. They stand between the handles of the brace-head, each one taking hold of two handles so that their hands lap. Then, assisted by the springing action of the pole in the return movement, they bear down and release or drop and lift the rods, by the handles of the brace-head, as the case may require at the beginning or end of the drilling to impart the blow with the drill, at the same time they walk around the rods to the left to prevent the rods becoming uncoupled, taking a step with each blow or two so as to turn the rods and drill in the hole while cutting.

The play of the spring pole varies from 4 to 8 inches at the beginning of drilling to from 12 to 14 inches at a depth of 200 feet. After drilling 4 or 8 inches, as above, depending upon the depth of the hole, the hitch knot is loosened by a splicing-iron and the drill, rods and brace-head are lowered so that the drill-bit comes within an inch or more of the rock, depending upon the weight of the rods. This process is repeated until the hole becomes so filled

with drillings as to impede progress. Not more than one or two feet can be drilled at a time when it is necessary to draw out the rods and remove the drillings with the sand-pump, as described further on.

After the drill and its rods have been sunk so that the brace-head comes too near the platform to permit of the men readily operating it, then the spring-pole rope, and brace-head are removed and the rods lifted and the first joint is held on the platform by the foot-wrench, while the rods are changed or other lengths added. Such lengths as may be desired by increments of 2 feet can be obtained by combinations of the 2-, 4- and 6-foot lengths and finally adding a 12-foot rod and repeating again the additions of the 2-, 4-, 6- and 12-foot rods as the hole becomes deeper. The 12-foot rod remains in place to form the increasing length of the drill-rods. The lowering of the rods with the increasing depth of the hole is described under " Lowering of the Drill-Rods."

At the beginning of the drilling, when the weight of the drill-rods is not so great, the adjustment of the spring-pole rope is such that as the rods suspend therefrom they will be a few inches above the rock. This depends also upon the spring of the pole. The blows are then effected mostly by bearing down on the handles; the return by lifting the rods, assisted by the spring of the pole.

As the hole becomes deeper and the weight of the rods heavier the blows are delivered by the downward weight of the rods in addition to the bearing down on the handles. The return being effected by the spring of the pole.

All drilling being necessarily done in the presence of water, if such is not present in the stratas of the rock, the small quantity needed must be arranged for. There must be sufficient to always keep several feet of water in the bottom of the hole for the most rapid progress and the greatest depth of drilling between the removals of the rods.

The reamer, Fig. 10, is used to true the hole if any ridges or projections have been left in drilling, or to enlarge it if the drill-bits become worn so that the hole is less than the regular size. The reamer is worked in the same way that the drill is operated. The fishing tools, Figs. 15 and 16, are for removing drill-rods or the sand-pump, if they drop or become detached in the hole.

Removing the Drill-Rods.

In order to remove the drillings by the sand-pump the rods must be withdrawn as follows:

The spring-pole rope, swivel and brace-head are removed from the drill-rods. The swivel of the windlass-rope is coupled upon the top of the drill-rods and lifted until the first joint comes above the platform. The foot-wrench is then applied to the squared portion of the rod below the joint and the windlass-rope is released so that the weight of the rods suspend by the foot-wrench as it rests on the platform. The rod above the platform is then detached from the lower rods by the hand-wrench applied to the squared portion of the rod above the joint, while the foot-wrench remains firmly in place on the platform. When the upper rod is removed the swivel of the windlass-rope is lowered and attached to the top of the rod suspended in the jaw by the foot-wrench. The length of rods is then again raised by the windlass and the weight on the foot-wrench is relieved, which is removed and again grasped around the next lower rod as this is raised above the platform by the windlass. The operation is then repeated of letting the weight of rods rest on the foot-wrench and removing the swivel of the windlass-rope, uncoupling with hand-wrench, and so on until the whole length of the rods is removed.

Use of the Sand-Pump.

The sand-pump, Fig. 13, is then lowered into the hole with a half-inch rope into the mixture of drillings and water, and is worked up and down by pulling up and letting go of the rope until the settlings have been well stirred up in the hole. The settlings then enter the pump through the clack-valve at the bottom. As soon as the pump is down as far as it can be lowered and is filled with drillings it is raised by hand or by the windlass and emptied. The hole will be cleaned after drawing up two or three sand-pumps full of drillings or as soon as the water discharges clear from the pump. By sounding with the pump it can be distinguished when the sand-pump has reached the bottom of the hole by the sharp jar in dropping it while holding the rope taut.

If the drillings are very heavy or pasty, it is necessary to use the sand pump, Fig. 14, which is lowered with the drill-rods and

operated similarly as in drilling until filled with sediment, and is then removed.

Heavy drillings occur in drilling through hard or flinty sandstone, spars, iron stone, etc., forming a coarse drilling as compared with that of easier-cutting formations—shales, slates, etc.

Pasty drillings are formed in the presence of clayey slates, tending to slack in the presence of moisture, etc.

Examination of the Drillings.

The drillings should be carefully examined, especially when searching for thin strata or seams. When the drillings from the neighborhood of such horizons are raised they should be poured out in separate places and allowed to dry for examination.

When a change in the hardness of the rock or formation occurs, the penetration of the drill into it can be distinguished by the difference in the sounding, ringing or yielding of the drill, due to the increased difficulty or ease in cutting. In this case, or when approaching the formation being sought for, drilling should stop and the rods be removed and the hole cleaned. The depth of the hole is noted at these various stages. Drilling is resumed, an inch or so being driven at a time, until the nature of the formation entered is determined. If it is one of importance, the drillings raised each time are poured out, dried and kept separately.

In coal-beds, as in other formations, the quality may vary at certain portions of its section. For this reason, each few inches of the drillings therefrom is kept separately for such examination and analysis as may be necessary.

Removing the Casing.

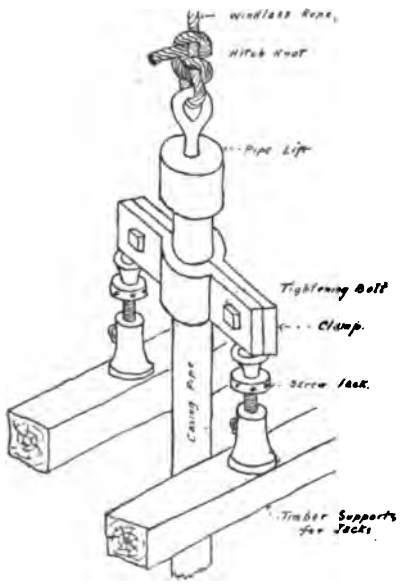
After the hole has been drilled to completion, the pipe casing is withdrawn and the hole abandoned, unless it is to be used for some other purpose.

To remove the casing, the pipe lift, Fig. 5, is screwed to the top of the piping and the windlass rope tied to it. If the casing is very shallow, the pipe can be raised by the windlass if at the same time a long pipe or chain wrench is applied to the casing, turning it in the same direction as in coupling, but with sufficient force to turn the whole length in the ground.

If the casing is of considerable depth, it is necessary to bind two iron clamps securely to the pipe below the shoulder of the

pipe lift. Two screw jacks, resting on solid timbers laid across the platform and bedded in the earth, are then placed under these clamps, one on either side of the pipe. Power is then applied to both at the same time, and as they begin to loosen the pipe from the soil, it is pulled upon by the windlass rope. This arrangement is shown in Fig. 18. The pipe may be thus readily loosened or it may require a continual use of the clamps and jacks, readjusting them with each few inches play of the jacks, to remove all the casing.

FIG. 18.



If the friction of the pipe against the soil, in removing it, is not sufficient to support it while uncoupling, it is supported by means of the clamps, as follows: The pipe is raised 6 or 12 feet, as most convenient for uncoupling. The clamps are then secured around the pipe just below the joint, and allowed to rest upon the timber supports, while the lengths above are uncoupled with a pipe wrench and removed. The pipe lift is then coupled to the pipe above the clamps; the latter are removed, and the pipes again lifted further up the hole by the windlass, the clamps again applied, and so on until the casing is removed.

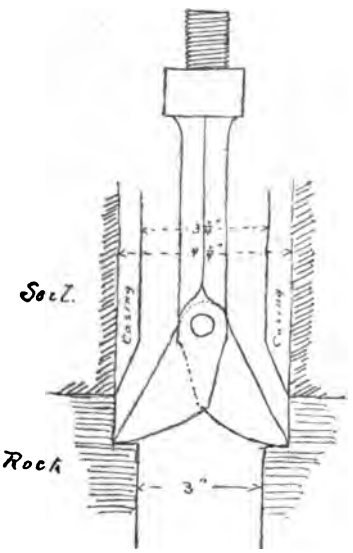
Obstacles and Special Appliances in Drilling.

A few difficulties are here described that are sometimes met with in drilling. The outfit that has been considered does not provide for overcoming all of them, as those difficulties requiring special appliances and are not of frequent occurrence. The method of overcoming these obstacles is here described in a general way.

If the soil contains small caving gravel, sand, etc., it can generally be pierced with the piping assisted with the auger.

Conglomerate or cement gravel can generally be pierced by the drill, but may tend to become loosened and fall into the hole and wedge the drill rods.

Fig. 19.



Expansion Drill.

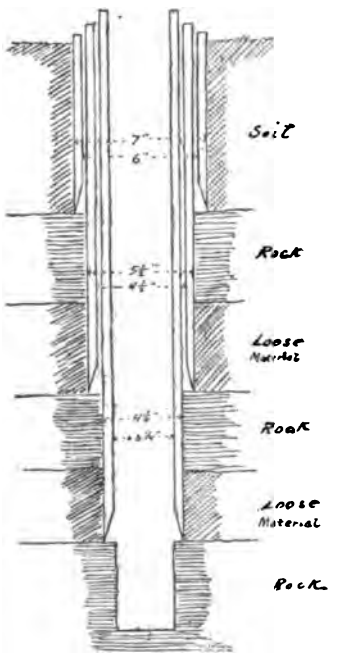
In either of the above cases, or where the gravel is large and caving, or if there are boulders present, it will generally be found necessary to sink a shaft to bed-rock.

It may occur that, after casing off the soil and drilling through rock, a considerable depth of loose material will be encountered. Either a shaft will have to be sunk from the surface down through the lower strata of loose material or else the 3-inch hole drilled in the rock is gone over with an expansion drill and enlarged suffi-

ciently so that the casing above can be driven through the rock and the lower bed of loose material.

Expansion Drill.—Fig. 19 shows one of the forms of expansion drills suitable for this work and its method of operation. The drilling bits are caused to spread to the desired gauge for drilling, either by their shape or by springs or by the action of the drill-rods.

FIG. 20.



Multiple Casing.

Multiple Casing.—Another plan is to sink casing pipe, 4½ or 4¾ inches inside diameter, through the first soil to the rock, and from there to drill a 4½-inch hole to the lower loose material, which will permit of entering the smaller casing pipe inside the larger casing and driving it through the lower strata of loose material to the rock, and the drilling of the 3-inch hole can then begin at that point.

If there are repetitions of the above formations, either the plan of expansive drilling or the plan of multiple casing can be used.

Fig. 20 shows the method of multiple casing through two strata of loose material below the surface.

Swelling clay slates are sometimes encountered which require continual reaming of the hole to prevent its closing.

Speed and Cost of Spring-Pole Drilling.

This will vary with the size of the hole and nature of the formations traversed.

The outfit considered has been for drilling a 3-inch hole, although similar outfits are arranged for drilling 1½ and 2-inch holes. The latter are adapted for shallow holes or for strata known in advance to be soft enough to be penetrated by a light-weight outfit.

The former outfit is preferable for general use, especially for the maximum depth of hole mentioned, or where some hard-drilling rocks are encountered, or if it should be found that, after starting to drill a 3-inch hole, that a strata of loose material exists below the rock, the hole will then be large enough to let a smaller casing pipe down in the 3-inch hole to the rock below, and from there drill a 1½ or 2-inch hole.

A 2-inch outfit can be readily operated by two men.

In Pennsylvania and Ohio spring-pole drilling of 1½-inch and 2-inch holes have in instances been driven at the rate of 8 to 10 feet a day for the first hundred feet and 4 to 8 feet a day for the second hundred feet. For holes averaging 150 to 180 feet deep the contract price is as low as 65 cents a foot from the surface, the contractor furnishing the outfit.

The strata in these cases are generally 10 to 30 feet of soil, with limestones, sandstones, slates and shales below.

In some instances of drilling 3-inch holes about 200 feet deep, the average rate of driving has been 6 feet a day, requiring 34 working days for completion, the speed being 7 to 8 feet a day for the first hundred feet and 4 to 5 feet a day for the second hundred feet. The contract price being 90 cents a foot from the surface, the outfit being provided for the contractor.

The speed of drilling in this instance is somewhat slow due to some hard flinty sandstones encountered. Following is given the section of the strata in which this drilling was done, 43 feet of surface soil and large loose gravel being excavated before drilling began.

	Feet.	Inches.
Soil and loose gravel,	43	0
Sandstone,	8	0
Slates and layers of soapstone,	56	0
Hard sandstone with slates,	49	0
Hard sandstone,	12	0
Slates,	8	0
Slates and hard sandstone,	14	0
Slates,	12	0
Hard sandstone and slates,	10	0
Coal,	1	0
Slates,	3	0
Coal,	3	6
Total depth,	219	6

As compared with diamond drill boring, 1¼-inch hole in similar formations, the following are the relative speeds:

Depth.	Number of Feet Drilled Daily.	
	Spring-Pole Drill, 3-Inch Hole.	Diamond Drill, 1¼-Inch Hole.
0 Feet to 100 Feet	7 to 8	20 to 18
100 " " 200 "	4 " 5	20 " 16
200 " " 300 "	3 " 4	18 " 14
300 " " 500 "		16 " 14
500 " " 900 "		14 " 10
900 " " 1000 "		9

The average speed of boring a 1¼-inch diamond drill hole 200 feet deep is 18 to 20 feet a day or about 11 days for its completion. For an 800- or 900-foot hole the speed is 16 to 18 feet daily or about 43 to 49 days for its completion. For a 1000-foot hole the average speed will be about 15 feet daily or about 60 days for its completion.

The moving and erecting of the diamond drill from one location to another preparatory to operating, especially in rough countries, is more expensive than with the spring-pole outfit. Allowing 3 days for changing position in addition to 11 for drilling a 200-foot hole it will require about 14 days for drilling a 200-foot hole with changes of location, or about 24 holes 200 feet deep can be drilled yearly, equal to a total of 4800 to 5000 feet yearly.

About the same number of feet will be drilled in a year if the holes are of greater depth, say up to 900 or 1000 feet, in the case under comparison.

With the spring pole a 3-inch hole 200 feet deep would be completed in 34 days. Allowing one day for moving and erecting, about 35 days would be required to drill a 200-foot hole and change location, or about 8 or 9 holes 200 feet deep can be drilled yearly, equal to a total of 1800 feet yearly.

Following is given the comparative cost of drilling with the spring pole and the diamond drill in the case under consideration, where they have been operated under similar conditions:

Cost of Spring-Pole Outfit and Drilling.

Following is given the cost of a 3-inch spring-pole drilling outfit, including labor and material.

Drilling Tools.

Spring pole, cut and rigged,	$ 5 50	
Windlass, derrick, etc.,	14 75	
Lumber for platforms, casing, etc.,	3 00	
Ropes,	7 25	
250 feet of 1¼-inch by 1¼-inch iron for rods, 52 pounds per foot at 4 cents,	52 00	
Joints for rods,	30 50	
Special iron, steel, etc., for tools, 300 pounds at 6 cents,	18 00	
Forming and shaping special tools,	55 00	
Machinists' and other tools,	15 00	
		$201 00

Pipe-Casing Tools.

Pipe driver,	$ 4 50	
150 feet of 3¼-inch casing pipe, threaded at 75 cents a foot,	112 50	
Forming and shaping special tools,	15 00	
Machinists' and other tools,	15 00	
		$157 00
Total,		$358 00

The cost of moving, sharpening tools, repairs, etc., for each hole will be about as follows:

Moving, erecting, digging pit, etc.,	$ 7 50
Carpenter work, lumber, nails, etc.,	6 25
Blacksmithing, sharpening, repairs,	10 50
New ropes,	4 25
	$28 50

The daily cost of labor, drilling a 3-inch hole is as follows:

1 head driller,	$2 50
1 helper,	1 25
2 laborers at $1,	2 00
	$5 75

If 6 to 7 feet are drilled daily the cost per foot will be 82 to 96 cents for labor.

The total cost of drilling per foot will therefore be:

Interest on cost of outfit = 10 per cent. of $358 = $35.80 by 1800 feet per year =	$ 0 02
Cost of moving, sharpening, $28 50 ÷ 200 feet.	14
Cost of labor per foot or contract price per foot,	90
Total cost per foot,	$1 06

Cost of Diamond-Drill Boring.

Following is given the cost of drilling a 1¼-inch hole with diamond drill.

The daily cost of labor drilling:

1 foreman,	$ 4 00
1 helper,	2 50
2 laborers at $1.50,	3 00
1 driver,	1 00
1 team, hauling fuel and water,	1 50
Total,	$12 00

If 18 to 20 feet are drilled daily, the cost per foot will be 60 to 70 cents for labor.

The cost of dismantling, moving and erecting for each hole is as follows:

Drilling force, 3 days at $12,	$36 00
1 additional team 3 days at $1.50,	4 50
Total,	$40 50

The total cost of drilling per foot will therefore be as follows:

Interest on cost of diamond-drill outfit, estimated at $5000 at 10 per cent. = $500 ÷ 5000 feet per year,	$0 10
Labor drilling, $12 ÷ 18 feet daily,	70
Moving, erecting, etc.; $40.50 ÷ 200 feet,	20
Fuel and water, $2 50 daily ÷ 18 feet,	14
Diamonds, 24 karats yearly at $16 a karat = $384 for 5000 feet, or .0048 karats per foot at $16,	07
Repairs to boiler and machinery about $200 yearly,	04
Total cost per foot,	$1 25

Provided there was a sufficient amount of drilling to soon absorb the first cost of a diamond-drill outfit, and other conditions were favorable, the cost of diamond-drill boring per foot will not greatly exceed that of spring-pole drilling.

If fuel and water are scarce, this item of cost as above shown, will be greatly increased.

In conclusion, the conditions first mentioned governing the use of the spring pole are: 1. Where only a small amount of drilling is to be done. 2. If only moderate cost is to be incurred. 3. If great speed is not required.

MELTING AND REFINING GOLD BULLION.

By H. VAN F. FURMAN, E.M.

The melting and refining of gold bullion and the preparation of gold amalgam for retorting are operations which appear to be imperfectly understood by many mill superintendents, if one judges by the frequency with which extremely base bullion is deposited at the government mints and assay offices.

Deposits of gold bullion may be classed as follows:

Grains, generally the result of placer washing. The gold is usually quite fine and free from impurities other than sand. Placer gold frequently contains small quantities of lead and occasionally sulphides, especially if derived from streams below stamp mills. Another class of grains are those derived from the washing of small pockets of very rich ores which are sometimes encountered in veins. These frequently carry pyrite and other minerals which were associated with the gold in the ore.

Amalgamated grains, generally derived from placer washing. As many placer miners working on a small scale have but imperfect facilities for retorting the amalgam, these grains frequently contain mercury in addition to sand and clay.

Retorts, generally the result of stamp mill operations. If the result of the treatment of free ores these are generally quite free from impurities other than sand. If the result of the treatment of sulphide ores they frequently contain lead, copper, arsenic and sulphides. The retort gold from Gilpin county, Colorado, while generally the result of the treatment of sulphide ores is usually

quite free from large amounts of these impurities, showing care in the preparation and retorting of the amalgam. Retorts are occasionally received which contain large quantities of water and mercury, showing great carelessness on the part of those entrusted with the preparation of the bullion. The base character of retorted bullion is sometimes due to the employment of foul quicksilver in milling. As quicksilver is readily purified, and as the use of foul "quick" invariably results in the loss of gold, this practice cannot be condemned too severely.

Bars, which may be the result of amalgamation, chlorination, leaching, smelting or placer washing. The bars from amalgamation usually contain the same impurities as the retorts, unless they have been subjected to thorough refining during melting, which is not generally the case. Bars from chlorination works generally contain copper, sulphides (where sulphuretted hydrogen is the precipitant employed), iron (where ferrous sulphate is the precipitant employed), and more or less lead. Arsenic is also a constituent of these bars from some works.

Bars from leaching works usually contain the same impurities as those from chlorination and also zinc (where zinc is the precipitant employed, as is usual where the cyanide process of extraction is used). These bars are frequently very base and difficult to refine.

Bars from smelters may be divided into two classes: parted or fine bars and unparted bars, the latter frequently being unrefined. The parted bullion generally contains no impurities worth mentioning, small amounts of silver and copper, together with the gold (usually over 990 fine), constituting the bullion. Occasionally small amounts of lead (sufficient to render the bullion brittle) are present. Unrefined bullion from smelters frequently contains copper, arsenic, lead and various elements which were constituents of the ores.

Jewelry and old plate which is generally deposited in the form of bars or kings. These usually contain considerable amounts of silver and copper but are otherwise quite pure. Iron (from watch springs, etc.), is sometimes present.

All of these deposits, except the parted bars and those derived from chlorination and leaching, contain considerable amounts of silver and require parting prior to coinage. These are the principal impurities although other elements, as bismuth, antimony, tellurium, etc., are frequently present in small quantities.

Effect of Impurities.

Antimony, arsenic, lead, sulphur, tellurium and zinc render the gold brittle and unfit for rolling even when present in such small quantities as $\frac{1}{2000}$ part. Zinc when added to gold in large quantities produces a ductile alloy.

Iron, aluminum, nickel, cobalt, platinum, palladium and rhodium form ductile alloys with gold.

The presence of lead is indicated by the fracture which is granular and has a silver-white lustre. The fracture of bullion containing arsenic is the same except that the color is a grayish-white resembling lead.

If the bullion is free from impurities, other than silver and copper, simple melting is all that is necessary in order to produce a ductile and homogeneous bar. Should other impurities be present they must be removed by refining.

Melting.

The bullion is melted in clay, sand or graphite crucibles. It is usual to place the crucible in which the melting is performed inside of a larger graphite crucible in order to avoid danger of loss should the melting pot crack or break.

A wind furnace using coke or charcoal, the latter is preferable, serves all purposes, but where many melts are made the gas furnace is to be preferred on account of the facility with which the temperature can be controlled.

The crucible should be heated gradually in order to avoid its destruction by cracking, and finally at a high temperature.

The bullion is now introduced, the crucible is covered and the temperature is raised. A plumbago stirrer is placed in the furnace so that when the bullion is melted the stirrer will be hot. This stirrer is a bar of plumbago about 8 inches long, 1¼ inches wide and ¾ inch thick and is slightly curved and flattened at one end to facilitate the removal of the slag. When the bullion has melted down and is perfectly fluid the cover is removed from the crucible. If pure the surface of the melt should be perfectly clear and present the appearance of a mirror. If not clear refining is necessary. If clear the melt is thoroughly stirred when it is ready for casting. The crucible is removed from the furnace and its contents are quickly poured into an iron mould which has previously been heated and greased with beeswax. In order to avoid loss by spat-

tering, the mould should not be filled more than two-thirds. The mould is covered and as soon as the bullion solidifies the bar is turned out and immersed in a bath of dilute sulphuric acid. This operation, called "pickling," serves to remove any slight stain from the surface of the bar and gives it a handsome appearance. Some operators use a dilute solution of nitric acid for this purpose. Should the bar show slight sulphide stains they may be removed by washing with a dilute solution of potassium cyanide. After pickling, the bar is washed in water and any adhering slag is removed by hammering and washing.

Refining.

Impure bullion may be refined by fluxing in the crucible, by cupellation or by parting in acids after melting with sufficient silver to ensure parting. Parting is generally preceded by cupellation or crucible refining.

Crucible Refining.—After the bullion has been melted as above, it is subjected to the action of certain fluxes for the removal of the impurities. Sand is removed by the addition of borax glass, or borax glass and sodium bicarbonate to the melt, the resulting slag being lifted off with the stirrer. The stirrer should be of the same temperature as the furnace, in which it should remain throughout the operation. Iron and black sand are removed in the same manner.

Lead is removed by the oxidizing action of nitre which is thrown on the surface of the melt from time to time. Borax glass is added with the nitre, to stiffen the slag and render its removal easy. Towards the end of the operation the surface of the melt presents a play of colors as in cupellation and after this ceases fine threads may be seen continually crossing each other. The lead is now nearly all removed and the bullion is liable to bubble or boil at this stage but soon becomes quiet and perfectly clear when it is ready for casting. Small quantities of lead are readily removed by the addition of oxide of copper, but some refiners object to the use of this reagent as it introduces copper into the bullion. Should the amount of lead present be large the oxidation by nitre will be tedious. When large quantities of lead, arsenic, or sulphides are present, bichloride of mercury may be used to advantage. The salt is broken into small lumps which are thrown on the melt from time to time. The bichloride sinks into the melt

where it is decomposed, the liberated chlorine permeating the liquid mass and rapidly oxidizing the impurities. This reagent should never be used except where the furnace is provided with a wide throat, a strong draft and a hood to carry off any fumes which may escape. On account of the dangerous nature of the fumes this reagent is not largely used. Ammonium chloride is also used but its action is much less rapid than that of the mercury salt. At the Royal Australian mint chlorine gas is forced through the liquid melt both for the removal of impurities and silver, the chlorine oxidizing the impurities and converting the silver into a chloride which rises to the surface.

Arsenic is removed in the same manner as lead, it rising to the surface of the melt in the form of small oily globules.

Sulphur is removed in the same manner as lead and arsenic but should the amount present be large the operation will be tedious and the following method may be adopted to advantage: Prepare some strips of strap iron and as soon as the bullion is melted introduce them into the crucible. The iron decomposes the sulphides, forming an iron matte which rises to the surface. The matte is removed by skimming and is put aside for future treatment. This treatment is continued until the sulphides are all decomposed, when the bullion and slag are poured off into a mould. After chilling, the matte is removed and added to the skimmings, the whole being melted in a crucible, together with borax to recover the shots of gold which it contains. The result of this melt will be a king of bullion and clean matte or slag which may be discarded. The bar and king are now melted with nitre, and the small amount of sulphides present are removed by refining with nitre and borax. The result of this melt is generally a refined bar, although a third melting with nitre is sometimes necessary.

Other impurities are generally present in small amounts and are readily removed by nitre and borax.

Potassium nitrate is the reagent generally employed as the commercial sodium salt is not nearly as pure, and generally contains considerable chloride of sodium. Should much silver be present chloride of sodium is liable to result in loss by volatilization.

The refining is preferably performed in clay or sand crucibles. When only graphite crucibles are at hand, or where the melt is too large for the clay or sand crucibles, the refining may be carried on

in a graphite melting pot, the corroding effects of the nitre and slag on the graphite being lessened by throwing bone ash on the surface of the melt. This collects around the sides, absorbs oxides and forms a ring around the sides of the crucible which effectually protects them.

Refining by Cupellation.—When large amounts of lead, arsenic, sulphur, etc., are present crucible refining is slow and tedious, and cupellation may be substituted to advantage. Where a cupel furnace is not at hand a very good substitute may be readily arranged as follows: Saw off the lower part of a graphite melting pot about four inches above the bottom and tamp in with bone ash. Hollow out the cupel to receive the metal and place it in the throat of a wind furnace provided with a good charcoal fire. When the cupel is hot introduce the bullion, together with sufficient lead, place the cover on the furnace and give the fire a strong draft. As soon as the lead begins to drive, the cover is removed from the furnace, the operation requiring no further attention other than to keep the temperature at such a point that there is no chance of the metal solidifying or freezing before the lead is all removed. Should the metal chill before the lead is entirely removed, the small amount remaining may readily be removed by subsequent crucible refining.

Bullion which has been thoroughly refined will consist of an alloy of gold and silver with possibly some copper, and should be ductile and perfectly homogeneous. Brittle bullion may be homogeneous, but more frequently samples taken from different parts of the bar will show considerable differences in fineness.

Sampling.

Either of the following methods are to be recommended:

Cutting off diagonally opposite corners with a chisel. These clips are pounded on a polished steel anvil and passed through a set of hand rolls until rolled into the form of a ribbon.

Drilling, it being preferable to take four drillings as indicated in the sketch. Equal amounts of the a, a' drillings are mixed together for the a sample. The b, b' drillings are treated in the same manner for the b sample.

Where the bar is ductile and perfectly homogeneous the first method is preferable as the sample is in better condition for rapid weighing out.

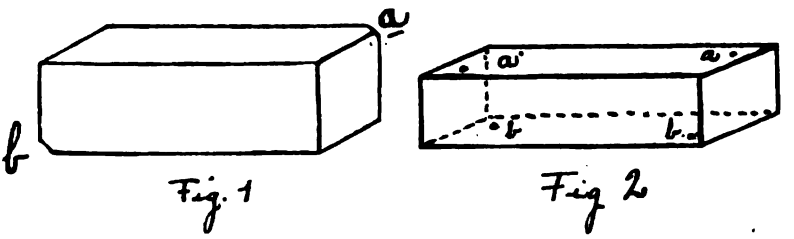


Fig. 1 Fig 2

Where the bullion is brittle and probably not homogeneous samples taken by the second method will more truly represent an average of the bar.

As the assay of gold bullion is described in most text-books it is unnecessary to enter on the subject here. The method adopted by the writer is described in detail in the second edition of *A Manual of Practical Assaying*, by the writer.

NOTES ON MINING.

By RICHARD A. PARKER, C. E., S. of M., '78.

The following pages are taken from my note-book of experience. They were written after reading the recently published *Text-Book of Coal-Mining*, by H. W. Hughes, and, as they apply to mining in general, I send them to the Quarterly, thinking that they may be of some value and interest to its readers.

Prospecting with Diamond Drill.—Besides having a knowledge of the mere mechanical details of the drill, and the method of operating it, a mining engineer, placed in charge of an exploring party, should be acquainted with the nature and peculiarities of the diamonds themselves. This information is often obtained only by dearly-bought experience.

For example, when confronted with a package containing anywhere from 100 to 300 stones, which ones should be selected? From their physical appearance, one cannot tell whether the selected diamonds will prove "soft" or not; those showing a cokey structure, however, should be rejected. Small stones are less economical than larger ones, because, sooner or later, they are worn down too small to reset in the bit, when what is left is practically

lost. A stone weighing less than half a karat would be difficult to set and have it retain its position while doing work, so that when worn to this weight it must be replaced. It is evident, therefore, that the greater the difference in weight between the original stone and when it is discarded, the greater service it has rendered. Thin, sharp-angled, wedge-shaped pieces are to be avoided, as also pieces with points. A straight edge, the sides of which form an obtuse angle (from 95° to 140°), will be found to be the more serviceable. If a well shaped stone is suspected of weakness, or shows a cleavage plane, it should be tested by a pair of hand-pincers, a simple instrument which has been often the means of detecting flaws and "soft" stones. Naturally, the stone dealers are averse to this test, but a purchaser is justified in making every fair attempt to ascertain the nature of the diamonds, as the dealers will not guarantee them in any way. When stones are selling for $15 a karat, it is very necessary that every precaution be taken that each stone purchased shall be as nearly perfect as possible.

Old stones, weighing a karat to a karat and a half, are worth far more than new ones of the same weight, as they have been not only tested, but the loss occasioned by the wear of sharp points or angles is obviated. Therefore, worn stones of suitable size are to be purchased in preference to new ones.

Diamond drilling in rock cannot be successfully carried on without water to keep the bit and stones cool, to wash the detritus from the cutting edges, and send it to the surface. This water is supplied by a small pump placed on the surface, and carried to the bit through the hollow drill-rods, core-barrel, and core-lifter. If the rock be dense, there is no loss of water, but if the drilling be carried on in broken strata, it may run off. Before drilling can proceed further in such a case, the seams which permit the waste of water must be made water-tight. This is done by sending down paper cartridges of bran, plaster of Paris, or hydraulic cement, which are broken by a rod let down for that purpose, and the contents rammed into the crevices. After allowing this material to harden or fill the openings, drilling is again resumed.

In metal mining, too much reliance must not be placed upon results obtained by the diamond drill, and close attention and study must be given to the form and nature of occurrence of the ore-bodies in the district. In coal regions this warning has not the same force, for very obvious reasons. In the first case, the lenses

or deposits have dips and pitches, which, together with the line and angle at which the drilling is done, should be accurately platted. To plat the drill-hole accurately, it is not sufficient to take the direction of the hole near the surface, but the fact that the rods may change, and probably have changed, their downward angle, must be considered. Attention to this matter should be given by those interested in prospecting work. A great deal of money has been spent in proving that the results of diamond drilling are at times deceptive. Confirmatory holes should always be drilled where there is the faintest possibility of being misled by the results of drilling as shown by the core.

Where work of this nature is done by contract, it should be of the essence of the contract that a reasonable amount of core should be secured for each foot drilled. In the case of soft hematite drilling, where the enclosing rocks are usually hard and costly to the contractor for diamonds, if ore be found the temptation is great to push through it, washing with water, and getting the red comminuted ore as an overflow at the collar of the hole, for it is under these circumstances that money is made by the contractor. Yet here, in the very material sought for by the prospecting, no core is obtained. It will not do to say that it is ore when there is no core, for talcose schist, heavily impregnated with hematite (locally known as "paint-rock"), may overlie the ore-body, and, like ore, yield no core. The probability then would be that the width of the "paint-rock" would be included in the estimated thickness of the ore-bed and lead to erroneous conclusions.

When holes are to be bored to a considerable depth, the cost depends, among other things, upon the number of times the rods are lifted; and, to economize time, the fewer lengths into which the joints of the rod are "broken" (unscrewed), the greater the time saved. Where practicable, and a deep hole is to be drilled, a tripod, made of iron pipe, 3 or 4 inches in diameter, the legs of which are 60 to 80 feet long, will be found better than shorter pieces of timber, as the latter are frequently difficult to get of serviceable length.

Rock-Drills and Bits.—In most of the modern percussion drills, the valve motion is controlled by the movements of the piston, and so long as the machine is new, and there is a good fit between the piston and the cylinder, this type of drill will perform its work satisfactorily. But when either cylinder or piston have worn so that

air, under the working pressure of from 60 to 80 pounds per square inch, can travel or leak from one end to the other, then this leaking air will tend to throw the main valve too soon, which results in a cushioned blow. As regards the bits, in soft ground, which drills readily, their diameter is of little importance, but in hard jasper-schist, where twenty to thirty drills are dulled before a foot of ground is bored, it is a matter of some moment. The depth that the hole is intended to reach is a determining factor, the main point being, that if the holes are too small, there will not be enough space for the clearance of the comminuted rock. Then, as against this fact, it must be remembered that the drilling progresses so slowly that there is but little *débris* to be removed from the hole. If it be argued that larger-sized holes permit a larger cartridge of dynamite, then the percentage of nitro-glycerine in the cartridge may be increased.

At the Champion mine, Beacon, Michigan, a drill-bit varying in form from those in common use, has been considered to yield better (*i.e.*, faster), results in cutting jasper-schist than the ordinary X or Z bits; it consists of a single V-cutting edge, the gauge of which is partly protected and retained by a set of cutting edges placed a little above either end of the bit, and at right angles to it. The principal objection to this form of bit is the difficulty of sharpening it, but when the blacksmith is accustomed to its peculiarities, it takes but little longer than the commoner X form, with a marked advantage in its rate of cutting.

Many local problems are met in every mine where machine-drilling is practiced, the solution of which depends upon the ingenuity and capacity for observation of those in charge.

Shaft-Sinking in Quicksand.—There are few situations in mining practice more trying to the engineer than sinking shafts through quicksand. Hundreds of thousands of dollars have been spent in attempting to do it, and even with heavy expenditure, failures are not unknown. One simple expedient has proven of great value in such work; that is, to sink two shafts so close to each other, that the drainage of water from one to the other will be comparatively free. In the one, which would not be the main shaft, the greater number of pumps are placed, giving more room in the other for the workmen and less liability to loss of pumps in case of inrushes of water and sand. The auxiliary shaft not being so large as the main shaft, lighter timber could be used.

In a paper by William Kelly, in the *Transactions of the American Institute of Mining Engineers* (Vol. XX., p. 188), a complete account of work performed in sinking a timber-shaft through quicksands is given, and is worthy the attention of those who may be placed in a similar position.

With regard to linings, shafts for coal-mines are generally planned for a longer life than those in metal mining. In European practice the former are curbed and lined with brick, and very frequently circular in section. In metal mining, the shaft is timbered, and is almost universally a parallelogram, varying from 5 by 7 feet to 7 by 20, or in the case of the deep shaft sunk at the Hamilton-Ludington mine, at Iron Mountain, Mich., it is 7 feet by 21 feet 3 inches in the clear, while the ground broken averages 9½ feet by 24 feet. This shaft is over 1400 feet deep, and was sunk over 90 feet in one working month. There are four skipways and four other working compartments, for timber, ladder-way, pumps and wires. The skips are 42 inches square by 16 feet long, and are estimated to contain 10 long tons of hematite iron-ore.

The centre-cut system of drilling is employed in the shaft, the centre holes being deepest, usually 9 feet. The second set of holes, which are 3 feet back, are 8 feet deep, and more nearly vertical than the centre holes. The next, also 3 feet back from the second set, are 7 feet deep; the remaining holes are put down to "square up" the shaft. The "sink" is usually 5 feet deep. There are 4 sets of holes drilled for the 2 centre cuts, and 3 sets for the 4 outside cuts, 4 for the ends and 1 hole in each corner, making 32 holes in a round. About 200 pounds of powder is used for each blast. The powder contains 45 per cent. nitro-glycerine, the centre holes being charged ⅓ heavier than the others. Thirty-seven men are employed in the two shifts, day and night, this number including the surface help at the shaft. The timber used is 16-inch pine, dressed square, one 16-inch and two 8-inch dividers, leaving four spaces, each 4 feet 8 inches by 7 feet in the clear. One and one-half inch iron bolts are used in the centre divider, and 1¼-inch bolts on the sides.

The material through which this shaft is sinking is dolomite; it is uniform in its density, and therefore drills and breaks readily. When nearer the surface, and sinking through slates, the ground was hard to "spend," as the slates stood on edge, and were therefore difficult to drill and blast.

The practice that obtains in coal mining relative to the number

of shafts might well, in many cases, be followed in metal mining. When the ore-deposits are small and uncertain in their downward course, it is but natural that the several bodies or lenses should be provided with separate shafts, but where they are of generous proportions, it is customary to sink shafts at distances varying from 300 to 600 feet apart, so that the maximum underground haul would average from 150 to 300 feet. It is claimed by the advocates of this practice that it enables the management to attack the ore-body in a number of places, and added hoisting facilities are obtained; but it may be shown, however, first, that the cost of sinking shafts (usually and properly in the foot-wall rock) is greater than driving headings in ore to the point reached by the shaft; and, secondly, if the hoisting-engines are of sufficient power at the several shafts, by taking up heavier loads, and being constantly kept at work, the same result will be reached more economically.

To help in obtaining the latter result, it will be found of advantage to build, upon the several levels at the landing station small pockets capable of holding twenty or thirty skip-loads. This insures a load for the skip being always in readiness; in the absence of such pockets it frequently happens that trammers are delayed until the skip can serve them. These underground pockets, therefore, facilitate hoisting in two ways; always having a load ready for the skip, and providing room for trammers to deliver their ore and depart.

The difference in cost between tramming 300 and 500 feet is very small, and may be disregarded when the cost of sinking and the maintenance of a separate shaft is considered. To operate a shaft, even if it does not require an extra engineer and brakeman on the surface, it does demand a skip-tender, day and night, and calls for repairs on the skipway track and landing-men at each of the several levels producing ore.

Again, in those cases where shafts are sunk in the ore-body, a very great loss is sustained in the locking up of ore, because, to remove it would destroy the shaft. In my opinion, the practice of putting down shafts at such short intervals is to be much deprecated; there is nothing gained by it save a somewhat quicker access to the ore-body, while the loss of ore, caused by the necessity of keeping it standing in the mine to support the shaft, far outbalances this meagre advantage.

Mine Timbering.—From the time of the introduction of the

"square-set" system in the Comstock mines, up to 1886, there was no attempt to change from the regulation rectangular joints and tenons. About that year, however, one Goodhue invented machinery for turning round collars and tenons; square tenons called for a number of relatively high-priced men to cut and fit them, and when taken in the mine, they frequently would not enter the mortise, causing a loss of time in cutting and adjusting. With machine-work this could not happen. Again, with the round tenon, in case the movement of the soft ore caused timbers to slew around, the caps readily adjusted themselves to the strain; while in the square form, the change of direction of pressure frequently caused the posts to split.

Underground Haulage by Electricity.—Two electric haulage plants have been recently installed in the Lake Superior iron regions—at the Lake Angeline mine and the Lake-shaft mine of the Cleveland-Cliff Company. Figures as to their economy over manual tramming are not yet available, as neither mine has been operated to its capacity since the installation of the plant. It is confidently expected, however, inasmuch as the *average* haul in the Lake Angeline mine will be somewhere between 600 and 700 feet, that some economy will be realized. The first thing one notices in their operation is the fact that distance underground is annihilated in cases where, with manual tramming, the distance would be prohibitory, thus calling for a second, or possibly third, shaft, with their attendant expense of maintenance. In the second place, though over 1200 feet from the shaft, the air in the face of a drift is thoroughly fresh; no hanging powder smoke or dead air is noticed. The motor rushes up and down the drifts at a rate of 8 to 20 miles an hour, sending currents of air up the raises and in every direction. This is a great feature of commercial and mining importance, and one that could not be obtained through any other system of underground haulage. The track is 2-feet gauge, of 28-pound rail, spiked to ties with a 5-inch face, laid 15 inches apart, centre to centre. The motor weighs about 9000 pounds, and is about 3½ feet wide, 7 feet long, standing 3 feet above the rails. A trolley-arm specially designed for low drifts is used, consisting of four pieces arranged in a diamond form and fitted with a universal joint at the base, to accommodate the angles which the trolley-arm assumes at different times, while operating on switch lines.

In a hematite mine, the rails are apt to become slippery and therefore dangerous in a down grade, on account of the greasy, unctuous ore. Sand has been used to prevent runaways, but the sand space on the motor is very limited. The cars are of the ordinary form, holding about 2½ tons, and provided with a buffer and coupling irons, similar to railroad equipment. Two men are employed with the motors—a switchman and motor-man, and it is expected that they will easily handle an output of 20,000 long tons of iron-ore monthly, with an average haul of over 600 feet.

The wires in the mine are run close to the centre of the roof of the drift; between them and the roof is a thin board, with flanges nailed on the sides so as to conduct moisture to the edge when it will drop free of the wire. The latter is known as size O and is quite hard; 4 O wire is used to convey the current (550 volts, 30 to 40 amperes), to the shaft, whence a large cable is used to deliver the current to the several levels. This cable is covered with okonite, then encased in a lead tube which is covered, and all is enclosed in a wooden box well tarred, inside and out.

The dynamo is known as the D 62 type, of the Thomson-Houston make—running at 900 revolutions. Since its installation it has given satisfaction in every way.

When the drifts leading to the shaft are planned to care for the coming in of four to six cars (10 to 15 tons of ore) at once, then there will be undoubtedly great economy in the use of the conveniences already mentioned, as for instance, pockets at the several levels, capable of holding say 40 tons of ore, so that the skip need not wait for the arrival of a train of ore, nor the cars for the coming down of the skip; but as soon as the train reaches the shaft pocket, let the cars be dumped and run on to a siding if not needed, or back to be reloaded.

The original cost of installation is apt to be high, but when the quantity of material to be moved can be approximated in advance, the cost of tramming by hand being also quite closely known, the difference in cost, between motor and manual hauling should pay for the plant; but, it not only hauls cheaper than hand-work, but gives ventilation as well, and permits the locating of shafts outside in the country-rock, which will not tie up pillars of ore. These are advantages to be taken into consideration when planning any form of mechanical haulage.

In this connection it is to be remarked that some few of the

catalogues issued by the trade interested in this and kindred subjects, are admirable in their technical and mechanical treatment of the appliances and machines made by them; very noticeable is the one issued by the Trenton Iron Company upon the subject of haulage, cables, grips, rail-switches, etc. It is a book worthy of place in every engineer's and mine manager's library, and its reading will well repay those interested.

Hoisting Engine Indicators.—An important adjunct of a hoisting engine is the indicator, for showing the position of the cage or skip in the shaft or at the surface. Frequently, where there is but one level to hoist from, the position of the cage is known by the amount of rope on the drum. But this is clearly insufficient, as accidents have occurred through over-winding, which would have been averted if the engineman had been provided with an indicator which worked accurately. An accident recently occurred at the Calumet and Hecla mine whereby eleven lives were lost, through a defect in the indicator. The cage was raised to the shaft-head and the rope pulled out of the socket, allowing the men and cage to fall to the bottom.

No cage for men or material should be hoisted, unless the engineer can know at any time its exact position in the shaft. There is a variety of forms of indicators operating accurately, and the several prominent manufacturing firms, M. C. Bullock Mfg. Co., Chicago, E. P. Allis & Co., Milwaukee, Lidgerwood Co., New York, and Webster, Camp & Lane, Akron, Ohio, all have devices of their own, which are simple, positive, and effective. The one made by Allis & Company consists of a tall post surmounted by a dial, upon which the landing places in the mine are indicated, and two arms or fingers. One of the latter is stationary until the other index shows the cage at the first level from the surface, when, sweeping around the arc at a comparatively rapid rate, it overtakes the other arm at the instant the mine cage or skip is at the uppermost point in the shaft-house, both fingers then being at zero of the dial; it is by far the best miniature device to be seen in the lake district.

Drainage.—The question of Cornish *versus* direct-acting force-pumps has often been discussed. Its original cost is the greatest objection to the Cornish pump. When the life of a mine is an unknown or uncertain element, the advisability of placing a Cornish pump may be questioned. The use of tanks or balers has been

demonstrated to be the cheapest known method of raising water, as the original outlay for the plant is limited. Steam can be utilized expansively at the surface and near the boilers, thus saving both in condensation and by the type of engine used.

As an instance of cheap work in raising water in tanks it may be cited that 26,520 pounds of soft coal used in twenty-four hours has raised 2500 gallons of water per minute from a depth of 1325 feet; in other words, one pound of coal has developed 1,800,000 foot-pounds, a duty that speaks volumes for the system. The figures here given are taken from a record of regular work done at the Hamilton mine at Iron Mountain, Mich.

Ventilation.—It would be of advantage to the student in ventilation to read the paper recently published by the American Institute of Mining Engineers, written by D. Murgue, Engineer of the Bessèges Coal Company, upon some "Experimental Investigations on the Loss of Head of Air Currents in Underground Workings." An elaborate set of experiments gives the actual and theoretical values of the currents in mine workings of various forms and dimensions, and in a diagram at the close of the paper, is shown a set of cross-sections of equal "loss of head" for arched rock and timbered gangways, with their equivalent areas. These figures are so interesting and instructive that I quote them here:

	Square Metres.
Arched brick-lined gangway,	2.2890
Rock gangway,	3 5680
Timbered gangway,	4.3800

While, of course, it is readily understood that the friction of air in a timbered gangway is greater than in one of either rock or brickwork, I know of no other place where figures of definite results and comparison can be found. It shows that almost twice the amount of space is required in the first instance than in the last named. This pamphlet will well repay perusal by any one interested in this subject.

Lighting of Mines.—Now that nearly every large mine has a dynamo furnishing an electric current for its surface illumination, it is a comparatively small matter to wire the principal underground passages for incandescent lighting. The light is so vastly superior, both for steadiness and intensity, that it makes its way against cheaper illuminants. Again, in metal mines, it affords greater

security from fires than lamps or candles. The bulbs are made of thicker glass and are more cylindrical in shape than those for ordinary use.

The only objection to their use in metal mines is where the ore is mined in large chambers, leaving pillars to support the roof. There the light serves to intensify the darkness, and is apt to render the miner timid by the fear of falling masses from the roof, which, at times, is just made visible by this light. If his radius of vision were limited to 15 or 20 feet, and all above were shrouded in darkness there would be nothing to excite his apprehension. The old adage holds here, that "seeing is believing;" seeing the roof, the miner believes a part of it may fall at any time; he is reminded of its existence, and therefore becomes more afraid of it, while, of course, it is not one whit more or less dangerous because he can or cannot see it.

A TREATISE ON OZOKERITE.

By EDGAR B. GOSLING, E.M., C.E.

Ozokerite.—(Ozocerite, native paraffine, mineral wax, fossil wax, Neftgil, Napthagil. Germ.—Ozokerit, Erdwachs, Erdharz, fossilerparaffin. French—Ozocérite, cire fossile. Polish—Wisk.)

I.—General Introduction.

We find, in nature, a group of solid, simple hydrocarbons, of high molecular weight, known as "Urpethite, Ozokerite, Zietrisikite," etc., which are closely related to petroleum, and which are frequently associated with it.

Ozokerite, the principal one of this group, was discovered in 1833 by Dr. Mayer, at Slanik, province of Moldavia (Ger., Moldau), in Roumania. Its name was given to it by Glocker, and is derived from the Greek, ὄζω, I swell, κηρός, wax.

We have a number of varieties of ozokerite, grading into each other according to their different paraffin (paraffin discovered by von Reichenbach, in 1830, as a product of dry distillation of wood) and oil contents, which varies considerably, and which gives rise to varying chemical and physical properties. The variations are

not only found with specimens from different localities, but also when taken from the same locality. Furthermore, the separating lines between the ozokerite varieties and those of urpethite and zietrisikite, which two latter are often associated with the former, are very indefinite. This has caused a number of controversies which probably otherwise would not have occurred.

II.—Properties and Probable Formation.

Ozokerite is a substance like wax or spermaceti in consistence. Its odor is like that of petroleum, and increases when heated. Its average hardness is about that of beeswax, but varies with the amount of petroleum or naphtha it contains. The softest varieties showing most of these, while varieties containing a small amount have been found to reach the hardness of gypsum. Ozokerite is more or less greasy to the touch, owing to the same cause. Its color, depending on the amount of impurities (sand, earthy material, petroleum, naphtha, etc.), ranges from the pure translucent honey-yellow kind to the yellowish-green, brown-green, blackish-green, to black variety, becoming more and more opaque as the impurities increase. It is more or less opalescent. Some specimens are dichroic (*e.g.*, show different colors when viewed from different directions), often dark-green by reflected and a pure yellow by transmitted light.

It has a fibrous fracture, and can be cut into chips with a knife. Under the microscope and polariscope, ozokerite shows aggregate polarization in the thickest parts of the slide, and a yellowish color; near the borders, the whole divides itself into thin hairlike needles, which are exceedingly fine and colorless, and which polarize separately, and are placed at right angles to each other.

The melting point varies between 58° C. and 80° C., but some rare specimens have been reported to have a melting point of 100° C., and over (probably zietrisikite), but the average melting point may be said to be from 60° to 66° C. When the melting point falls below 58°, a large quantity of petroleum may be presumed to be mixed with the wax.

In regard to the variations of the melting point, it has been found that the melting point of the paraffin-like body derived from ozokerite increases, as a rule, with the specific gravity, as shown by the following table:

Melting point.	Specific gravity.
56° C.,	0.913
61°,	0.921
67°,	0 927
72°,	0 934
76°,	0 940
82°,	0.943

It is not, however, to be concluded from the above that a specimen of ozokerite, having a melting-point, as per table, will have the corresponding specific gravity.

The melting-point of ozokerite may also be said to vary with the amount of petroleum or naphtha mixed with it. Ozokerite, which has from 10 to 15 per cent. of these, will have a melting-point at from 60 to 65° C., while varieties with traces of these have same up to 100°.

It is to be remarked that the determination of the melting-points having been made by different methods, we find much diversity in the results of different writers on this subject. A convenient method and very exact one of determining the melting-point is to dip thermometers into the melted material. Then to immerse these bulbs below the surface of a considerable body of water in a beaker exposed to heat. As the temperature rises, the material adhering to the bulbs becomes liquid (not merely pasty), detaching itself from the same and rising to the surface; by this method a fraction of a degree may be noticed.

The boiling-point varies between 210° C. to 300° C., and in some cases even higher, and probably runs up above 380° C., for varieties approaching the Zietrisikites.

When experimenting for the boiling-point with Utah ozokerite, a sudden leaping of the mercury column in the thermometer has been noticed. The thermometer, after gradually rising to about 300°, suddenly jumped to the top of the tube, and on cooling, fell almost as suddenly to 270°.

The specific gravity of ozokerite is from 0.85 to 0.97.

On distillation, ozokerite, under ordinary pressure, decomposes, but in case it is distilled in vacuo it can be brought over without decomposition. It burns with a good flame and leaves little remainder.

It is easily soluble in oil of turpentine, benzine and naphtha or petroleum; little soluble in boiling alcohol, from latter solution it separates out in crystals; it is soluble in boiling ether (this prop-

erty is one that " Dana " uses as the principal distinguishing feature between ozokerite and zietrisikite, which latter is almost insoluble in boiling ether); it is soluble in carbon disulphide.

The crude mineral is *very* slightly attached by concentrated sulphuric acid.

It is not dissolved by alkali.

After long treatment with strong nitric acid it is changed into succinic, butyric and valeric acids. When treated with chlorine in the presence of $SbCl_5$ at 360° it yields CCl_4, C_2Cl_6, C_4Cl_6 and C_6Cl_6.

Ground in a mortar it becomes positive electric.

It is a non-conductor of electricity.

The chemical composition of ozokerite varies, as is shown by the analyses of kinds from different localities.

Locality.	Carbon. Per cent.	Hydrogen. Per cent.	Authority.
Slanik,	84.43	14.39	Schroetter.
Truscawitz,	84.62	14.29	Walter.
Boryslaw, A,	84.94	14.87	Hofstadter.
Boryslaw, B,	85.78	14.29	"
Turpeth,	86.80	14.00	Johnston.
Utah, A,	85.44	14.45	Smith.
Utah, B,	85.75	15.15	"

The chemical analysis of ozokerite aids us very little in the determination of its molecular composition. The latest authorities agree that it is not a homogeneous substance but a mixture, and therefore not a definite mineral species. This is shown by the action of solvents or by fractional distillation, which allows us to separate it into two or more substances. It is further probable that the substances of which it is composed belong to the paraffine (C_nH_{2n+2}) as well as to the olefine (C_nH_{2n}) series. Some authors consider it chiefly composed of bodies of the paraffine series, while others seem inclined to place its chief constituent in the olefine series. Various formulas (determined by Raoult's freezing process or by the " kryoskopic " method of determination of molecular weight) have been given to it; all of these have a carbon multiple from 20 up to 30, and we find formulas as

$C_{24}H_{50}$ $C_{25}H_{52}$, $C_{26}H_{54}$, $C_{27}H_{56}$, $C_{30}H_{62}$ and $C_{24}H_{48}$, $C_{30}H_{60}$, etc., assigned to it; but as stated above:

It is, chemically speaking, not a well-defined body (in this respect similar to most of the other natural hydrocarbons), and is probably a mixture of paraffines and olefines.

From a geological and genetic point of view, ozokerite and petroleum are probably inseparable; they are found in the same geological stages, principally in tertiary and cretaceous territories, and, as a rule, the petroleum, when accompanied by ozokerite, is found at the lower level of the two. The solid product is, in reality, only a petroleum containing a high percentage of a paraffine-like body (30–50 per cent., in rare instances 60 per cent.), and shows, on analysis by fractional distillation, the same constituents in different proportion, as will be seen by the following comparative table:

Component Bodies.	Petroleum. (American.) Per cent.	Ozokerite. Per cent.
Naphtha and benzine,	41	17–28
Lubricating oils,	39	15–20
Paraffine-like body,	2	30–50
Residue and loss,	18	10–20

Mixtures of petroleum and ozokerite, showing a regular passage from the former to the latter, are found, giving rise to various varieties at same localities. (See later on.)

The question now arises how the transition from petroleum to ozokerite took place. One of the best-known theories (it assumes the formula C_nH_{2n} for ozokerite), and the one most generally accepted, is that it has been formed by the oxidation and decomposition of the hydrocarbons of naphtha and the elimination of water, and that the salt clays, or similar deposits, which are usually found near ozokerite deposits, are the materials that eliminate the water. This gives a reasonable explanation why ozokerite is not found associated in the American petroleum fields, where, no such material being present, we find frequently vaseline-like substances as an offset to ozokerites.

Putting the above theory into chemical formulæ: if we take, for instance, naphthalene and oxidize, we get dinaphthyl containing no oxygen, *e.g.*:

$$2C_{10}H_8 + O = C_{20}H_{14} + H_2O.$$

Suppose we now take such a body as octane (C_8H_{18}), and oxidize, we have

$$2C_8H_{18} + O = C_{16}H_{32} + 2H_2O, \quad . \quad . \quad . \quad . \quad . \quad (1).$$

By oxidizing further, we get:

$$2C_{16}H_{32} + C_8H_{18} + O = C_{24}H_{48} + H_2O, \quad . \quad . \quad . \quad (2).$$

According to this hypothesis, one can lead easily back to the formation of petroleum from marsh gas as well as show clearly the relationship between ozokerite and petroleum.

The low specific gravity (0.74–0.828) of the oils produced by the distillation of ozokerite, as well as the high percentage of the paraffine-like body it contains, is a guard against the theory that the wax was produced merely by the evaporation of petroleum leaving a thickened substance behind, and we find some authorities advocating that it was formed by the placing together of original organic fat and naphtha and the subsequent oxidation and condensation; but the few fossils found in the regions of the ozokerite deposits do not seem to bear out this theory.

III. Occurrence, Geology, Etc.

A. *In the Carpathian Mountains.*—Before mentioning the various localities at which the principal ozokerite deposits of this range (as well as of the world) occur, it will be of interest to say a few words of the general geology of these regions. The Carpathian mountain range lies chiefly in Austro-Hungary, but extends also to the Servian frontiers, into Roumania and to the Black Sea. The range is rich in minerals, and besides petroleum and rock-salt, it contains gold, silver, mercury, copper, iron, etc.

The strata which will be of interest in regard to the ozokerite deposits will be found in the following table; they are energetically folded in the direction of N.W. to S.E. They contain but few fossils.

Tertiary.
- Neocene—Calciferous Clay.
- (Miocene) (Saltthon grappe).
- Eocene.
  - Sandstone of {Kenoa / Magura} layers with Nummilites — Carpathian Sandstone.
  - Menilite Shale.
  - Sandstone of Libusza.
- Neocomian (lower greensand formations).
  - Calcareous Sandstone (hieroglyphs and fucoids).
  - Layers of Ropianka or Inferior Carpathian sandstone.
  - Trachytes of Wernsdorf.
  - Schists of Teschen.

In all these layers petroleum occurs associated frequently with rock-salt; besides, one finds gypsum, native sulphur and many sulphurets, such as blende, pyrites, galena, etc. The most remarkable occurrence of this kind is at Truskawice, where, in the neighborhood of a mineral spring, a deposit of native sulphur and sulphurets (argentiferous galena, blende and calamine), mixed with gypsum, ozokerite and petroleum, is found. Iodine and bromine have also been found.

a. Boryslaw, a small town near Drohobycz, Galicia, contains by far the largest deposit of ozokerite (deposit discovered by Dom in 1854) known, and the exploitation (started in 1859) takes place here on the largest scale. The ozokerite is found, at a depth of from 40 m.–80 m. below the surface, across a soil of schists and miocene sandstones, in an irregular series of true veins, from a few millimeters to many meters in thickness. Deposits in lumps of several hundred pounds are also encountered. The overlying strata are, first, a coarse sand of 8–10 m. depth; then, second, a blue clay and loam, containing frequently layers of slate, sandstone and marls to the depth of the ozokerite.

The mining is of a very irregular nature on account of irregularity of deposit (this may be said in general of all ozokerite mining). It is by means of shafts and galleries of small dimensions and requiring considerable timbering. The shafts (5000–6000 in 1867, from 12,000–13,000 in 1887) are on an average about 60 meters deep, but shafts up to 210 meters have been sunk; the diameter of the shafts is about 1.5 meters. They are frequently so close together that when getting out of alignment they touch each other at their bottom. The ventilation, pumping and raising of the mined material are of the crudest nature, as a rule by hand fans, hand pumps and windlass respectively. A French company started in 1879 (about) to mine on an extensive scale with steam appliances, etc., but has not been successful. The mining offers great dangers. In the deep workings what is known as "Blasenwachs" is sometimes encountered. This is a soft variety of ozokerite, which oozes out of the fissures due to the pressure of the overlying rocks. It has been found that the deeper one goes the softer the wax, as a rule, becomes, not only on account of the increase in temperature, but also on account of a diminution in density; at same time the proportion of liquid and gaseous petroleum augment, and it is possible that at a certain depth one may find only

liquid petroleum, often so rapidly that it actually floods the shafts, hardly allowing the workmen time to escape. Besides, gas is continually encountered, giving rise to explosions, although safety-lamps of Musseler & Mersant type are used. The mortality from accidents is about two per cent. per annum.

The yield of wax is in general about four to eight per cent. of the mineral mined. Various varieties are distinguished at Borys-law and neighborhood. They are separated according to their hardness, color or petroleum or naphtha contents, and are as follows:

1. "Kenderbal," *e.g.*, soft variety containing large quantities of naphtha, yields a paraffine of very low melting point (below 58°) is very dirty and very greasy to touch. 2. "Blasenwachs," mentioned above, is about same as Kenderbal, but its melting point is slightly higher, and it contains less naphtha. These two varieties are the most inferior kind of ozokerite. We next have varieties ranging from brownish green, dark yellow to bright yellow in color known as (3) commercial ozokerite, with a melting point from 60° to 66°, and some rare varieties of bright yellow, with a melting point running up to 90° and more. These are known as (4) prima, (5) hockprima and (6) primissima, and paid more for being purer, etc.

b. At Dwiniacz and Starunia (Galicia).—About 35 kilometers south of Stanislaw. Veins and lumps of ozokerite are found about 5 meters from the surface in alternate layers of Carpathian sandstone and bituminous clay of miocene formation.

c. At Truskawice.—In sandy clays and marls associated with various sulphurets in the limit of the miocene formation.

d. At Teschen (Austro-Silesia).—In the neocomian schists strata.

e. At Wernsdorf and Parad.—In the neocomian trachyte greenstone.

f. At Neutitschein.—In marls, calcareous conglomerates and granular quartz accompanied by greenstone.

g. At Gersten, near Gaming.—In the miocene Vienna sandstones near deposits of coal, mostly in pockets.

h. At Libisch, in Moravia.

i. In the Province of Transylvania (Hungary-Austria).—In the Carpathian sandstone strata near coal and salt deposits.

B. *In Roumania.*—Detached branch of the Carpathian Mountains in the province of Moldavia.

At Slanik.—Beneath a bed of bituminous shale in the vicinity of cannel coal and rock salt.

C. *In the Caucasian Mountains*, along the north side of the range. Russia.—At Kouban, in the inferior tertiary and superior cretaceous formation first known about 1856.

D. *Caspian Sea.*—On the islands of Swajtoi and of Tscheleken, in granules and in pockets, deposits of very variable dimensions, accompanied by petroleum, near oil springs and above slate clays and much ckalk of the Aralo-Caspian miocene formation. (The ozokerite here is called neftgil, napthagil, etc.

E. *On the Coast of the Caspian Sea* (Truchmiena).—At Baku in the miocene formation; also at Derbent, Ekaterinodar and Kalochinsky.

F. *On the Transcaspian Region* (Asiatic Russia).—In the Neftedagh hills in the middle portion of same in veins about 3 inches in thickness across argillaceous marls and of a thickness up to 2 feet in sandy deposits, the former layers are pitch black, the latter greenish-brown to black. Both of miocene formation.

G. *Central Asia* (Russian).—In Turkestan on the southern shore of Lake Bal-Kash large deposits are reported.

H. *In Italy.*—At Monte Zola in the province of Bologna (reported).

I. *In England.*—At Urpeth near New Castle in a coal mine associated with Urpethite.

K. *In Scotland* at (*a*) *Kinghommes* and at (*b*) *Fuchheith* about 15 feet from the surface in nodules imbedded in solid volcanic trap. The formation is a curious one; the nodules consist of, first, an outer coating of hard rock; second, an inner lining of calcite crystals, and third, a central nodule of ozokerite the specific gravity of which is reported to be 0.97.

(*c*) At Midcalder the ozokerite is a green-brown, half solid translucent mass and is found in fissures of limestone. It shows .296 per cent. of nitrogen and is supposed to be the result of distillation and condensation of slate coal. First discovered in 1885.

(*d*) At Uphall in Linlithgowshire in vicinity of a coal bed.

L. *In United States.*—The most important deposits are in the Wahsatch mountain range (Utah), on the east flank of same, in paraffine oil shales. These oil shales extend into (*a*) Colorado (*b*) Arizona, and (*c*) New Mexico; and ozokerite has been reported from all these regions. These shales are probably of the Miocene

Tertiary formation. The area covered by them is about 400 miles from northwest to southwest and about 200 miles from northeast to southeast. They are not equally rich in wax; in some localities they are very rich in oil and pure in wax, in others, the reverse. We find below the richest zones of shales a series of compact beds, varying in thickness to 100 feet or more, which are full of fresh water Tertiary shell fossils. These shells are heavily impregnated with oil. The shale directly above is a very fine clay, with few fossils, and varies in thickness from 5 feet to more than 20 feet and it is in this that the ozokerite occurs. Above this layer a remarkable tough oil shale is found running up in thickness to about 100 feet; in this also, ozokerite occurs, but not frequently. The large amount of animal fossils seem to indicate that the ozokerite here might have been of animal origin.

The principle deposits of ozokerite in this region and the only one that is worked is at Soldiers' Summit, Utah.

The exploitation was started there in 1888 by R. J. Kruppa, for the Ozokerite Mining Company, which has a refining factory at Greenpoint, Long Island. The mining was started with 25 openings and more than a dozen veins were exposed in the same year. The deposit is said to be quite extensive (see statics later), It is to be remarked that the Utah, etc., varieties, can not be used for the manufacture of the purest refined variety, *e.g.*, Ceresine.

(*d*) In Wyoming near Laramie, ozokerite has been reported in the coal and oil fields of that region.

(*e*) In the Sierra Madre Mountains of Mexico and New Mexico, about 50 miles from Los Angeles, large amounts of a snow-white resinous substance, said to be ozokerite, were reported in 1879.

(*f*) In New Jersey, at South Amboy in the clay layers of that region, small pieces of ozokerite have been found. It is probable that they have been washed there from the petroleum fields.

M. *New Zealand.*—Deposit of ozokerite near Gisborne has been reported.

N. *Africa.*

(*a*) Egypt (reported).

(*b*) Oran (Algeria) (reported).

IV.—Treatment of Ozokerite.

The mineral that is brought to the surface before being refined undergoes a preliminary treatment. The following one, which is

practiced at Boryslaw, may serve as a guide for such treatment, part or all of same being resorted to at other localities.

The mineral product consists (*a*) of nearly pure ozokerite pieces and (*b*) of earthy gangue rich in ozokerite.

a. The nearly pure ozokerite is directly melted in kettles heated by direct fire, by steam or by boiling water (the latter method gives an easier product for subsequent refining), and cast into barrels, from which the staves are subsequently knocked out and the solid material cut into cakes and shipped to the refining factories.

b. The earthy gangue containing ozokerite undergoes four successive operations.

1. The lumps are flattened with a spade, the loose earthy material falls off, and the ozokerite picked out. All except about 10 per cent. is then obtained.

2. The remainder is then dumped into kettles full of cold water and stirred; the free ozokerite swims to the surface and is drawn off. About 4 to 5 per cent. of the ozokerite remains behind.

3. This remainder in quantities of from 200 to 250 pounds is dumped into kettles containing boiling water and the ozokerite contained melts and floats to the surface and is drawn off. Still about 1 to 1.5 per cent. of ozokerite remains behind.

4. The last remains are treated sometimes with benzine and steam; the earthy matter is washed with benzine in a sort of extraction apparatus. The ozokerite dissolves and is distilled over by steam. This operation is done in a closed vessel, and gives rise to no loss of benzine and purifies the ozokerite at same time. The benzine can nearly all be regained, and the product is more valuable than the ozokerite derived from the other previously described treatment. The ozokerite obtained from these preliminary treatments is melted and cast in forms, as already stated.

Two or three qualities of cakes are sold according to their color and earth contents. The first quality contains no earthy matter and varied from light yellow to brownish green; the second and third qualities contain up to 20 per cent. of foreign matter and their color runs to black. Great care must be taken in buying the cakes, as frequently earthy matter is buried in their centre.

Refining of the Cakes.—The following are the various methods that have been used according to the use, etc., the products are to be put to:

1. *Treatment of Battersea* (England), Field & Co.—Products used

principally for candles. (*a*) About 4000 to 6000 pounds of the cakes are melted in tanks, which are heated by steam coils. The melted mass runs into underlying retorts, whence (*b*) it is distilled by steam and direct heat under the retorts, until a very high temperature is reached. (*c*) The distillate runs from the receiver into forms, where it congeals into an oily mass of paraffine. (*d*) This mass is then pressed by hydraulic pressure, and most of the oil contents are gained. The remaining cakes are (*e*) again melted and pumped from the melting vessel with a steam pump into kettles in which it is (*f*) treated with sulphuric acid. These kettles are provided with steam jackets and stirring apparatus. The mass is allowed to defecate (clarify) and is (*g*)drawn from the bottom of the kettles into vessels in which it is heated again from the bottom, and from these kettles it is poured into forms. One obtains a white hard wax with a melting point about 60° to 65° C., which is suitable for the manufacture of candles. It is about 60 to 70 per cent. of the original cakes. Sometimes a portion of the mass after treatment with sulphuric acid is washed with hot water to remove any traces of the acid, and is then melted and treated with the coaly remainder produced in the manufacture of ferrocyanide of potassium and filtered through animal charcoal, poured into cakes and pressed. One obtains a more refined article of pure white color, *e.g.*, ceresine, which, when slightly given a yellowish color, is used for the imitation of beeswax.

2. *Treatment at Truchmenia* (*Caspian Sea*).—The ozokerite is not of as good quality as the Galician varieties; the treatment is very much like that at Battersea. (*a*) The cakes are subjected to fractional distillation in cast-iron flasks of about 1500 lbs. capacity, with steam-coils and refrigerating apparatus. One obtains a distillate about 65–70 per cent. of cakes composed of paraffin mass and oils. The former (yellowish-brown to brownish-red) is cut from solidification basins into cakes (*b*), which are pressed by hydraulic pressure; these are (*c*) melted by increasing temperature 170°–180° and about 5 per cent. H_2SO_4 added; (*d*) a little lime is now added, to neutralize the H_2SO_4, and about 25 per cent. of oil, resulting from first distillation, is added, and the whole is rapidly distilled. The distillate is poured into cakes, which are pressed and subjected (*e*) to superheated steam for about one hour, which removes the odor. The mass is melted in double-walled kettles and (*f*) washed with water and a little lye. This

eliminates a few clinging impurities; a little stearic acid is often added here. The liquid is poured into cakes.

The product is entirely colorless and odorless, bright and translucent, but very brittle and very difficult for use in candle manufacture.

In this process about 40–45 per cent. of average oil for lighting purposes and 30–33 per cent. of paraffin.

The light oils distilled over in the first distillation are used for the paraffin purification, as alluded to above; the others, resulting from the various pressings, etc., are subjected to fractional distillation, in order to get out all the paraffin. They are then treated with about 1 per cent. H_2SO_4, and distilled over lime or chloride of lime, and one obtains a light-yellow photogen of about .79 to .81 sp. gr., which has a mild smell and is not as inflammable as ordinary petroleum.

3. *Redl Process of Refining Ozokerite without* H_2SO_4.—Thecakes are firts (*a*) melted with about three times their weight of animal charcoal and well stirred for about six hours, then the whole is (*b*) treated in a suitable extraction-flask with benzine or sulphuret of carbon. The extraction materials are then eliminated, and one obtains about 90 per cent. of a white wax, which, however, contains about 15 per cent. of oil and other animal impurities. The product, therefore, cannot be used where high grades are necessary

4. *Redl Process, using* H_2SO_4.—The cakes are heated to about (*a*) 120° C., removing the light oils and then allowed to cool to 75°; then (*b*) about 50 per cent. of naphtha, of .70 to .72 sp. gr., is added. The mixture is gently agitated, and (*c*) 10 per cent. of fuming H_2SO_4 is added. After further agitation, the liquid is allowed to remain quiet for about half an hour; (*d*) caustic soda is then added, and the naphtha is removed by distillation, and (*e*) the whole heated and filtered through animal charcoal.

5. *C. M. Pielsticker Patent.*—(*a*) The ozokerite is melted below 100° C., with 10–12 per cent. of sulphuric acid and washed with hot water; it is then allowed to remain quiet and decanted. (*b*) 5 per cent. of carbonate of barium and caustic soda is then added, and through the whole a current of steam is passed cool. The mass, which is still yellow, is melted with animal charcoal in an apparatus having a mechanical stirrer, and the whole filtered and run into cakes, etc.

6. *Coignet's Patent* (1877).—If in raw state, the material is freed

from earthy matter by grinding into powder, then melting with aid of water-vapor, then acted on by superheated steam (283°) the paraffin and liquid hydrocarbons distil over as well as the amorphous ozokerite, which latter is retreated with superheated steam. The paraffin and ozokerite is separated from the liquid part by a filter of double effect, and is bleached by means of animal charcoal at a *high* temperature.

7. *Ujhely* cleans ozokerite by (*a*) dissolving in ether, naphtha, benzine or sulphuret of carbon (*b*) then filtering through bone-black or the remainder from the manufacture of potassium, ferrrocyanide, and (*c*) separates the solvents by distillation. The product is said to be pure ceresin (not recommended.)

8. *Hodges* cleans the cakes, by placing them on slightly warmed porous material, where the fluid parts are absorbed and the paraffin said to crystallize out, remaining behind.

9. *Henderson* uses a similar process, taking for porous material, felt or cloth, mounted on wire gauze.

10. *V. Ofenheim*, 1880 (*a*) melts the cakes and treats with 20 per cent. of hydrate of alumina, hydrated peroxide of iron, hydrated oxide of manganese, or hydrated oxide of magnesia and heats to 170–180°—after about one hour allows to cool to 100°—and to settle (*b*), the mass is then drawn off and treated again with new hydrates once or twice (*c*), then treated with steam until the ceresin has separated out. The hydrates can be used again after they have been dried.

11. *Ch. v. Chemin Process.*—So as to avoid the darkening of the ozokerite in melting, Chemin recommends the use of only low heat. He melts it in water whose temperature does not surpass 70° if possible (at 75° a darkening takes place) and the following process cannot be to full advantage applied to ozokerite cakes which have already been subjected to higher heats in their preliminary treatment. (*a*) The melted ozokerite is poured into a retort and 5 to 15 per cent. of flour of sulphur are gradually added by means of a sieve. (The heating of the retort and the introductions of superheated steam is done in the common ways used in steam manufacture.) The whole is uninterruptedly distilled and the distillate consists of a yellowish product which crystallizes on cooling. The product is poured (*b*) into forms and pressed. The cakes are kept at a temperature from 35–50° while pressing. The product is melted (*c*) in a water-bath at about 70° C. and then

amyl alcohol added and stirred thoroughly and poured into forms. The cakes are (*d*) pressed again, melted and stirred thoroughly with animal charcoal and filtered over animal charcoal. One obtains a hard, resonant product about 70 to 80 per cent. of rare material used.

NOTE.—The sulphur is said to act both mechanically and chemically, and has not the desired effect when the melting of the material has been at a high temperature.

12. *Young* cleans ozokerite by passing hydrochloric acid gas through the molten mass. *Meldun* uses sulphurous acid gas and washes the powder-like paraffin with a solution of paraffin in petroleum.

13. *Treatment for Ozokerite Vaseline.*—The ozokerite is melted and liquid allowed to filter through a series of charcoal filters such as used in sugar refineries, after passing through 12 to 15 of these, the liquid becomes wine yellow; to render it colorless and limpid as water double the number of filters must be used. When thus forced from all bituminous matter, it is brought in direct contact with superheated steam (250° C.) in a vessel known as a "duplicator." After remaining there about three or four hours, we get vaseline (about 25 to 30 per cent. of raw material used). The great difficulty with this process is the renewal of the charcoal.

NOTE.—On most of the ozokerite refineries concentrated sulphuric acid is used at high temperatures and the workmen are as a rule subjected to the noxious fumes of So_2. One factory only uses a stream of steam in connection with its appliances that leads off the SO_2 gas into a channel filled with burnt lime and then into open air; this plan although not perfect, should be further introduced.

Methods of judging of the quality etc. of ozokerite before treatment on large scale. Lach, gives the following method.

Take 100 grammes of wax and 20 grammes of fuming H_2SO_4, heat stirring, up to 170°–180° C. until no more fumes given off. Determine amount due to evaporation, add 10 grammes of the remainder from ferro-cyanide of potash manufacture, heat to 140° stirring the liquid, let cool. Take $\frac{1}{10}$ in a dry weighed filter and place in an extraction apparatus and draws out with boiling benzine (60°–80°). The amount of bleached wax is found by loss from filter or by evaporation of the wax dissolved in the benzine. According to the whiteness of the product the amout of H_1SO_4, to be used for the manufacture in large, can be judged.

The found proportion of product will agree to within 1 per cent. of actual production if the manufacturing is carefully conducted.

Sauerlandt gives the following method: Decompose the ozokerite by fractional distillation with super-heated steam. If one heats a good quality of ozokerite (that is suitable for ceresine manufacture) gradually in a distillation flask slowly to 120° only a little mineral oil of low specific gravity should go over, if one now allows steam to pass through the distilling wax about 3 to 7 per cent. of fluid carburetted hydrogen should go over; this one should be obliged to heat to about 300° before the mass should begin to distill over. The distillation then gradually becomes easier, and at 320° about 55 to 70 per cent. will have distilled over of which 45 to 60 per cent. is paraffin. When you heat still further in conjunction with super-heated steam up to 380° to 420° you obtain 15 to 20 per cent. of a resin-like oxygen holding yellow material having little or no paraffin contents. If one continues the distillation still further to dryness, burnt resins go over and we have remaining in flask a solid, thick coke. Resuming we get:

1. Easily boiling fluid carburetted hydrogen.
2. Paraffin melting from 60 to 62°.
3. Resin-like bodies.
4. Burnt resin.
5. Cokes.

The greater amount of paraffin melting from 60 to 62° produced in the operation the better quality of the ozokerite.

The latter process is tedious and the former is recommended.

Average Result of Distillation, etc. of Ozokerite from Different Localities.

	Boryslaw. A. Per cent.	(Galician). B. Per cent.	Persian. Per cent.	Urpeth. Per cent.	Colorado and Utah. Per cent.	Baker. Per cent.
Oils,	37.61	38.28	22.48	18.30	90.00	81.8
Paraffin mass,	56.58	52.27	53.55	64.95		
Coke,	2.85	4.63	16. 3	11.15	5.28	4.4
Loss by water gas,	3.00	4.82	7.24	5.60	4.72	13.8
Sp. gr. about,	0.93	0.93	0.925	0.89	.928	.903
Melting point,	60–66°	60–66°	.....	60–70°	76°	79°
Color, etc.,	Dark yellow variety.	Dark brown variety.	Dark green rather hard.	Soft and sticky as a rule.	Dark brown.	Dark brown to pitch black.

Caucasian ozokerite is said to be inferior to Galician ozokerite and only gives second quality ceresine.

Method of Deriving Crystalline Paraffin from Refined Ozokerite (Ceresine) (Zaloziecke).—The ceresine is dissolved in an excess of warm amyl alcohol; on cooling the mass will separate out in crystalline minute plates. Filter and press. Treat repeatedly in the same way; the final product after such treatment is melted and cast into shape required. It is a translucent distinctly crystalline substance resembling paraffin in its properties. The ingredients in solution in the different alcoholic fractions are pasty and soft, with very low melting point (32° to 40°).

Beilstein and Wiegand produced white glistening crystals, which they called "Lekene," from ozokerite (From Tscheleken). They distilled the wax in vacuo—dissolved the distillate in benzine and precipitated by absolute alcohol (96 per cent. alcohol at 16°). This Lekene had specific gravity of 939 and melting point 79° and they defined the ozokerite as a fossil resin consisting chiefly of a hydrocarbon called chene.

The principal refineries of ozokerite are: *In Austria* at Aussig, at Florisdorf, Drohobicz, Lemberg, Newpest, Hermanstadt, Stockerau, Vienna.

In Germany at Halle, Frankfort, and Hamburg.

In Russia Poland at Strzemiszya and Sosnowice.

In England at Battersea.

In France at Paris (neighborhood).

In United States at Greenpoint, Long Island.

V.—Production.

Production. in Austria.	Official Figures. Tons.
1877,	8961
1878,	10,342
1879,	9067
1880,	10,527
1881,	10,649
1882,	9930
1883,	10,630
1884,	11,967
1885,	13,026
1886,	13,925
1887,	8025
1888,	8780
1889,	7560
1890,	6170

The output of 1892 is reported to be 16,000 tons, of which Boryslaw yielded 10,000 tons, Starunia 3000 tons, Dwiniacz 1800 tons, and Truskawice 1200 tons. This is about the proportion of the yearly output from those localities.

Production from the Islands of Swjatoi, Tcheleken and Kouban Region.—They produce about 700 tons each annually. The production of the island of Swjatoi in 1877 was 36,000 puds (1 pud = 36 pounds about) or about 650 tons.

Production of United States.—From Soldier's Summit, Utah.
(Discov. 1885.)

	Pounds.
1888,	20,000
1889,	50,000
1890,	350,000
1892,	130,000

Imports in United States of Mineral Wax.

	Pounds.
1873,	25,135
1874,	380
1875,	7,430
1876,	16,525
1877,	101,604
1878,	69,884
1879,	44,963
1880,	103,973
1881,	98,911
1882,	272,509
1883,	565,658
1884,	617,992
1885,	1,066,438
1886,	800,496
1887,	718,769
1888,	1,164,940
1889,	1,078,725
1890,	1,069,241

NOTE.—Up to 1883 the table includes Brazilian and Chinese and other wax; from 1883 only ozokerite.

The average price of ozokerite in Europe is five cents per pound. In New York the price averages from six to seven and one-half cents per pound.

VI.—USES.

A. *For the Preparation of Candles.*—This is the principal use to which refined ozokerite is put. In 1839 candles made of raw and

of cleaned mineral wax were exhibited by "Sellegné," a French manufacturer at the Paris Exhibition; these candles were dirty in appearance, although the wax was white. Their price was from 120–180 francs per 100 kilos. Since then the ozokerite paraffin candle industry has developed greatly, and the ozokerite paraffin candles are said to be the best. This is due to the following reasons:

(*a*) The illuminating power of ozokerite candles exceeds that of the best paraffin candles from other sources and is far beyond the stearine and spermaceti wax candles. This will be shown by the following table which gives the number of grains of the various substances enumerated required to give the light of a 1000-grain spermaceti candle.

	Grains Required.
Ozokerite paraffine candle,	754
Best paraffine (from other sources),	798–891
Spermaceti,	1000
Wax,	1151
From various other compounds,	992–1189
Stearine compounds,	1200

(*b*) They have a high melting-point, and do not bend or soften in warm atmosphere.

(*c*) They burn with a dry cup, and are not so liable to gutter as ordinary transparent candles.

(*d*) They are entirely free from smell and not at all greasy to the touch, and resemble beeswax.

B. The oils derived from ozokerite refineries can be more safely used for illumination than the heavier petroleum oils, on account of their high boiling-point.

C. In the manufacture of illuminating gas, to enrich the latter.

D. In the manufacture of paraffin matches.

E. For the manufacture of ceresine; *e.g.*, a highly purified ozokerite. This use is next to that of the manufacture of candles in importance. Only the better varieties of ozokerite can be employed for this purpose. Ceresine is used to replace beeswax in all its applications.

Good ceresine can hardly be distinguished from beeswax except chemically, the latter being destroyed by H_2SO_4, while the former is not attacked.

F. For axle-grease, ozokerite has been used in a crude state from time immemorial.

G. For waxing of floors.

H. For shoemakers' wax and like purposes.

I. For stiffening and glazing of wash.

K. For the manufacture of colored lead-pencils.

L. For electrical purposes.

1. As a non-conductor of electricity it can partially replace gutta-percha, which is continually growing scarcer.

Cables are made with a covering consisting of a mixture of 2 parts of ozokerite with 1 part of gutta-percha (Latimer & Cast, manufacturers).

A compound of rubber and black ozokerite, which remains as residue in the stills in the Battersea treatment is used also as an isolator. The compound is known as "Okonite."

2. As a matrix for galvanoplastic. The electric deposits can be made to reproduce the finest contours and details, and the wax can be used over again. As the ozokerite is a non-conductor, the method of procedure is to cover the surface of the mould with silver or graphite powder, thus rendering it a conductor at its surface.

M. As a matrix for salves. After freeing the ozokerite from its smelling properties, it can be used as a matrix for salves like vaseline (see manuf. of oz. vaseline), it having the property of preventing rancidity, etc. These salves are mostly used for animals.

N. For the preservation of metal work, weapons, etc. A preparation called "Ozokerine," or "Virginia" is used by the German army for this purpose.

O. For the protection of sheet iron. By covering the iron with ozokerite and heating till latter is burnt; on cooling one obtains a varnish-like covering which protects the iron against atmospheric influence.

P. For the protection of paper, linen, etc., against acids and alkali.

VII.—Substances Allied to Ozokerite.

A. Urpethite found at the Urpeth Colliery, England; resembles ozokerite in all its properties and composition. The distinguishing features are, first, is readily soluble in *cold* water; second, melts at about 39° C.

Its oil or naphtha contents are higher. Composition (approximate): Carbon, 85.43 per cent. Hydrogen, 1.17 per cent.

B. Zietrisikite occurs principally in Moldavia. Hardly distinguishable from ozokerite.

The distinguishing features are:

First, almost insoluble in ether even when hot.

Second, its melting point seems above 90° C. Its oil or naphtha contents is very low and it is as a rule harder than ozokerite. Composition (approximate): Carbon, 84.53 per cent. Hydrogen, 14.22 per cent.

C. Baikerite, a brownish wax-like mineral found in the neighborhood of the Baikal Sea (Siberia); acts like ozokerite towards naptha, oil of turpentine, ether and alcohol. Melts at 52°. Possibly, ozokerite.

D. Hatchettite or Mountain Tallow, occurs in thin plates mostly and sometimes in crystals. Sp. Gr., 0.916. Melts at about 16° C. Composition: Carbon, 85.91 per cent. Hydrogen, 14.62.

E. Elaterite. Readily distinguished by its being elastic. Sp. Gr., 0.095—1.233. Composition: Carbon, from 83.6 per cent. to 86.17. Hydrogen, 12.5 per cent. to 13.2. Said to contain oxygen.

F. *Kabaite.*—A hydrocarbon resembling ozokerite found in meteorites (Woehler).

G. Posepnyte. A wax found in Lake County, Cal., is considered to be a product of oxidation of ozokerite (V. Schröchingen).

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NOTE.—The * signifies that the article is specially recommended.

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ELECTRICITY FOR MINING PLANTS.

BY EDWARD D. SELF, M.E., E.M.

THE cost of installing an electrical power transmission plant in regions remote from railways and the natural disinclination of mine managers to try experiments, have been important causes in delaying the application of electricity to mining and milling purposes. Another reason that explains the reluctance of mining companies, who sometimes undertake chimerical metallurgical ventures with surprising willingness, to introduce electrical appa-

ratus, is the widespread ignorance of electrical matters on the part of practical miners. It seems to be hardly appreciated yet yet that the operation of an electric motor under given conditions can be as easily predicted, as the operation of an engine or boiler. The thought of applying electric motors in mining operations, unfortunately seems always to suggest electric drills, subterranean trolley roads and hoisting plants—all of which involve peculiar conditions of insulation to prevent danger from fire or injury to men by bare wires and also other requirements not found in surface plants. The field wherein electricity is an unrivalled means of reducing the cost of mining work is not in its underground applications, where many details of construction have still to be determined by experience, but where it may be used for reducing the primary cost of a horse-power delivered at the main shaft of a mill or the drum of a hoisting engine. If, by electricity, we can secure cheap motive power at the prime mover, we may still use miles of compressed air pipes, innumerable air drills and winches, and, without doing violence to the prejudices of the miners, still effect a large saving in operating expenses. Having materially decreased the first cost of producing the total horse-power required, the inefficient manner in which a part may be distributed through the mine or mill does not make an item of so great importance in the expense account.

To illustrate the value that electricity may have as a factor in mining work let us take a case under conditions that sometimes prevail, and consider a 500 horse-power mine plant located in a remote district and dependent upon wood for fuel. As the surrounding forest is destroyed for timber and fuel, the cost per horse-power will steadily become greater. If the consumption of wood continues the expense for power alone will at last equal the value of the product of the mine and its profitable working must cease. The rapid destruction of the forest may be roughly calculated as follows:

Assuming an evaporation of 8 pounds of water per pound of coal (equal to 2.5 pounds of wood) and that the engines require 25 pounds of water per horse-power per hour, we find about 7600 cords of wood will be required annually for fuel alone. We may also assume that the large timbers are reserved for mining purposes and amount to, say ¼ of the wood cut. The total annual destruction of the forest will thus exceed 10,100 cords for a plant using only 500 horse-power. If 60 cords can be cut from

an acre, we will have to cut down 167 acres or .26 square miles per year to supply the requirements of the plant. At the end of ten years there will have been consumed an area 1 mile wide and 2 6 miles long. If the country were uniformly wooded and no other destructive agent had removed the wood, we should have cut the forest equally in all directions until the nearest standing timber would be nearly a mile from the boiler. These conditions, however, are too nearly ideal, for other causes, such as fires and the demands of neighboring mines, are also always active in removing the forest, so, doubtless long before the period mentioned, the visible supply of fuel would consist of a remote tract of timber-land, and, notwithstanding careful contracting, the cost of fuel would increase rapidly year after year. If wood cost $4 per cord at the mine, there would be an annual expense of $31,400 for a 500 horse-power plant. Adding to this the cost of repairs, attendants, handling wood, etc., the actual expenditure for power would amount to say $37,500, or $75 per horse-power per year. There are two methods by which the working life of a mine surrounded by such conditions may be materially prolonged. One is the construction of a railway to bring fuel more cheaply to the boilers, and the other is the utilization of the power of a distant waterfall by electrical transmission. As the ultimate fate of a boiler plant depending upon a receding forest for fuel has been made evident, let us determine how far we may be justified in transmitting the power to the mine. As a basis for calculation, take $4 per cord as the maximum price that can be paid for fuel and allow a reasonable profit on the product. To make the calculations approach possibilities of actual practice, suppose an electro-motive force of 2000 or 3000 volts is to be used on the pole line, and the simplest electrical appliances are to be employed. Since the cost of the generating and receiving plants will be substantially the same whether they are one or fifty miles apart, the problem becomes a determination of the possible distance over which it will pay to transmit the power.

Remembering that the weight of copper required for conductors varies with the square of the distance for a given electromotive force and also inversely as the square of the electromotive force for different voltages, if we determine the number of *dollars* that be expended a complete solution can be obtained for any electromotive force desired after knowing the total cost of copper per pound on the line.

Let us then put F_s = first cost of steam-plant.

P_s = percentage covering interest, depreciation and repairs.

C_s = wages, oil, waste, taxes, insurance, etc.

A = cost of fuel per pound of steam.

N = number of horse-power hours per year the plant is operated.

S = number pounds of steam per horse-power hour.

The annual cost of operating will then evidently be $P_s . F_s + A . N . S + C_s$.

Also let F_e = first cost of electric plant.

P_e = percentage covering interest, depreciation and repairs.

F_h = first cost of hydraulic plant required for driving generators.

P_h = percentage covering depreciation, interest and repairs.

F_l = first cost of copper conductors between generating and receiving station.

P_l = percentage covering depreciation, etc.

C_e = constant expenses electric plant.

C_h = constant expenses hydraulic plant.

C_l = constant expenses pole line.

The "constant expenses" include the salaries of attendants, linemen, dynamo-tenders, etc., that are approximately constant within a wide range of horse-power delivered. Although the fixed charges for the proposed electrical plant are for quite different service than the annual expense for engineers, firemen and machinists, an approximate estimate will show that they are about the same for each plant, and, therefore, may be omitted from each side of the following equation:

$$P_s \times F_s + A \times S \times N = P_e F_e + P_h F_h + P_l F_l.$$

Now, let P_s = 6 per cent. interest + 4 per cent. repairs + 4 per cent. for sinking fund for renewal of boilers, etc., = 14 per cent.

Take cost of steam-plant, $75 per horse-power, $37,500.

Taking $4 per cord for wood as equal to coal at $10 per ton, the boiler evaporation at 8 pounds and engine duty 25 pounds of water per horse-power per hour, we find the cost of horse-power per year with other expenses, as already calculated.

Let $F_e = 500 \times 200 =$ $100,000, an extreme figure, assuming special sectional machinery is required.

Let P_e = 6 per cent. interest + 4 per cent. depreciation + 4 per cent. repairs = 14 per cent.

F_h = 500 × 75 = $37,500 = cost of hydraulic plant.

P_h = 6 per cent. interest + 4 per cent. repairs = 10 per cent.

P_l = 6 per cent. + 2 per cent. repairs = 8 per cent.

We have now to find the value of F_l to ascertain how much may be spent for conductors and still keep the final total cost per year per horse-power at the present rate.

Substituting and reducing:

$$500 \times 75 \times .14 + 500 \times 75 = 100{,}000 \times 14 + 37{,}500 \times .10 + .08\ F_l.$$

$$\$25{,}000 = .08\ F_l.$$

$$F_l = \$312{,}500.$$

It is now a simple matter to find what distance the line can be run for the amount given, after fixing upon the electromotive force to be allowed between the terminals and the per cent. loss on the line. (See paper by Edward D. Self, in QUARTERLY for July, 1894.)

For this problem take 16 cents per pound as the cost of the copper. Here, as in the article cited, it would be manifestly unwise, for financial reasons, to expend $312,500 for copper, the amount theoretically allowable. There is, therefore, a wide margin for acquiring and improving water rights. Suppose we conclude to spend $50,000 for a pole line and operate the line at 20 per cent. drop, we shall then find it will pay to secure and improve by storage reservoirs or otherwise any waterfall within a radius of nearly 14 miles, if 2000 volts E.M.F. be employed, or 21 miles at 3000 volts pressure. The annual interest charge, if the entire sum be expended, would allow the same profit on the product of the mine as if fuel were being purchased at $4 per cord. By assuming the amount to be expended for pole line, etc., and substituting in the above equation we can determine the value of the electric plant in the price of wood per cord or coal per ton. The difference between the actual cost of fuel and the so-calculated cost may be taken as a convenient measure of the advantages of electricity over steam.

No further comment is required to emphasize the peculiar adaptability of electric transmission of power to aid in the solution of one of the most difficult of mining and milling problems—the disappearance of fuel.

CARBORUNDUM: ITS HISTORY, PHYSICAL PROPERTIES AND CHEMISTRY.

By JOHN ALEXANDER MATHEWS, B.S.

CARBORUNDUM is a chemical compound of carbon and silicon formed at the high heat of the electric furnace, and possesses properties making it valuable as an abrasive or grinding material. It is already supplanting emery, corundum and diamond dust in many industries which require the use of an abrasive.

Mr. E. G. Acheson, the inventor of the process of manufacture, made his first experiments leading to his invention of carborundum in the laboratory of Mr. T. A. Edison, at Menlo Park, N. J. A few years ago he became connected with an electric light plant in Monongahela, Pa., and there completed his investigations. The production of carborundum is the result of both discovery and invention. When Mr. Acheson began experimenting he hoped to obtain a crystallized carbonaceous product by letting the carbon crystallize out of a bath of melted silicate of alumina by cooling. He did obtain crystals by this method, but very soon discovered that they were not carbon alone but that the silicon of the clay used in the charge in some way was of importance. Since it was not the alumina which entered into the compound, he experimented with sand and carbon as the constituents of the charge.

Before this, however, Mr. Acheson, supposing that alumina was one of the essentials, decided to compound a name from "carbon" and "corundum." The result was the name "carborundum."

While still experimenting with clay and coke, it was found that the presence of 10 to 15 per cent. of salt as a flux facilitated the operation. The cost per pound was once as high as ten dollars and, of course, until the price could be brought to a much less figure, the invention would be useless for other than laboratory purposes, since it could not compete with the other abrasive materials on the market. The capacity of the works at present is about 300 pounds a day, and for this output of crude material and its manufacture into wheels, powder, etc., about 30 or 40 persons only are required.

Mr. Acheson secured his patent in the United States on Febru-

ary 28, 1893. His patent is No. 492,767, and is for the "production of artificial crystalline carbonaceous materials."

At the present time Mr. Acheson has been able to secure a patent in nearly every European country, and has sold his right in several countries for large sums.

The steps in the manufacture in order are: First, the materials used, consisting of a good quality of glass-sand, mostly obtained in Illinois; coke, ground impalpable, obtained from the Connellsville region, and good salt, are intimately mixed. The kind of coal from which the coke is made has considerable effect on the product. Sometimes powdered anthracite has been used. It is impurities in the coal which give the carborundum its color; the green color due to iron predominating. The proportion of the materials used are about four parts by weight of coke, five of sand, one or two of salt. In each charge nearly four times as much material is used as appears in the finished product.

The furnaces consist of a masonry foundation about three feet wide by eight in length. On this the furnace proper is built up after each charge. Its walls are of vitrified brick, and in the ends are inserted the carbon electrodes which are connected with the dynamo, supplying an alternating current, and thus preventing any electrolytic action. As many as nine carbons are often inserted at both ends, each being a foot long and two inches in diameter. The distance between the carbons in the opposite ends of the furnace is about five to five and one-half feet. In charging a furnace a core of loose carbon is laid between the electrodes, and it is around this carbon-core that the carborundum is produced.

It takes about eight hours for the formation of the product, after which some hours must be allowed for the substance to cool. It must not be understood, however, that the substance is formed as a liquid and crystallizes on cooling, for this is not the case. In the early days of the industry much trouble was experienced by reason of changing internal resistance due to the changing conditions of the materials constituting the charge. The carborundum forms in a hollow, cylindrical mass around the core, and it is from four to five inches thick. The line of separation between the product and the outer partially changed mass is quite distinct.

In most cases the carborundum consists of greenish crystals, sometimes, however, varying to sapphire tints or to yellowish green, but in the aggregate appearing quite dark and adhering

loosely together. The variation in color is probably due to the presence of metallic impurities. The crystals arrange themselves radially from the core and are usually flat, disc or needle-shaped.* Although always small, thus far experience has found that they increase with the size of the furnace. The many newspaper articles to the effect that there are formed large crystals resembling

* The following report on the crystalline form of crude carborundum was furnished by Prof. Frazier, of Lehigh University, to Mr. Acheson:

"The specimens examined were aggregations of crystals, the individual crystals, usually more or less disk-shaped, varying in their largest dimensions from a fraction of a millimetre to about three millimetres. The faces were usually smooth, with brilliant, adamantine lustre. The images reflected from them in the goniometer were frequently double or multiple, sometimes blurred, and sometimes broadened by diffraction. Occasionally, however, single, somewhat sharply defined, images were obtained.

"The color of some of the crystals was a yellowish-green; that of others varied from a bluish green to blue.

"The crystals were found to be rhombohedral, their disk shape being due to the predominance of the basal pinacoid. The observed forms consisted of numerous direct and inverse rhombohedra, with the basal pinacoid and, in some crystals, the prism of the first order. The following rhombohedra were observed and determined, viz, $\frac{1}{3}$, $\frac{4}{5}$, $\frac{10}{11}$, 1, $\frac{5}{4}$, $\frac{4}{3}$, $\frac{10}{7}$, 2, $\frac{5}{2}$, 4, $\frac{19}{4}$, 5, 10 No evident marks were discovered to distinguish direct from inverse rhombohedra. In one crystal the following grouping was observed:

Direct rhombohedra.	Inverse rhombohedra.
1	$\frac{10}{11}$
$\frac{10}{7}$	2
$\frac{5}{2}$	$\frac{19}{4}$
10	5

"In some crystals, like that just described, the rhombohedral symmetry was evident; in others, the direct and inverse rhombohedra of the same parameters were found on the same crystal, so as to impart to it an appearance of holohedral hexagonal symmetry. This holohedral habit was observed in bluish-green and blue crystals, while in those yellowish-green crystals, which were examined in the goniometer, the habit was rhombohedral. Further investigation will be needed to decide whether this coincidence is accidental or not.

"The value for the length of the vertical axis was calculated from four good measurements made on three different crystals, with the following results:

$$c = 1.2267$$
$$1.2261$$
$$1.2264$$
$$1.2264$$

giving the mean value, $c = 1.2264$.

"The following are a few angles between the most frequently occurring forms observed:

in color and appearance various gems, and which may be substituted for them, are without foundation in fact.

The product of the furnace is crushed in a pan by hard-steel rollers to separate the loosely-adhering mass. The mass is then treated to remove impurities by boiling for a week in dilute sulphuric acid and water, especially to remove iron and silicate of soda. After thorough drying the material is graded for the different purposes to which it will be put; the coarser grades are removed by sifting through sieves of various degrees of fineness. The fine powders are obtained by a process of flotation and are distinguished by the length of time they will float. Thus the powder is done up in packages labelled one-, three- or four-minute powder, as the case may be.

One of the great uses of carborundum is for making grinding wheels. They are made of all sizes, from the dentist's points for his revolving drills up to what are ordinarily known as grindstones, a foot or two in diameter, together with all intermediate sizes. As the powder possesses no great adhesive properties, a bond must be made use of before wheels can be moulded. The material is mixed with the bond by a churning process in revolving casks. The moulding of the material is the next step and is all done by hand. The moulded wheels are then laid on earthenware discs

	Calculated.	Observed.
$0 \wedge \frac{10}{11}$, ...	52° 09′ 42″	52° 07½′ to 52° 14½′
$0 \wedge 1$, ...	54° 46′ 22″	54° 43½′ to 54° 50½′
$0 \wedge \frac{8}{9}$, ...	60° 32′ 15″	60° 32′ to 60° 46½′
$0 \wedge \frac{10}{7}$, ...	63° 41′ 49″	63° 41½′ to 63° 43½′
$0 \wedge 2$, , ...	70° 33′ 12″	70° 31′ to 70° 38′
$0 \wedge 5$, ...	74° 13′ 39″	74° 13½′ to 74° 15¾′
$0 \wedge 10$, ...	85° 57′ 39″	85° 56¾′ to 86° 02′
$1 \wedge 1$ (terminal), . . .	90° 04′ 43″	
$2 \wedge 2$ (terminal,) . . .	109° 29′ 43″	109° 30½′

"It is worthy of notice, in view of the isometric crystallization of the diamond, that the rhombohedron chosen as the unit rhombohedron has almost the shape of the cube, while the rhombohedron 2, a frequently occurring form, in combination with the basal pinacoid has very nearly the shape of the regular octahedron.

"No distinct cleavage was observed.

"In one instance, a twin was observed, two disk-shaped crystals being so grouped that their basal pinacoids made an angle of 109° 29′ + with each other. This would conform to the law, twinning plane, that of the unit rhombohedron.

"A flat crystal, examined under the microscope in converging polarized light gave the interference figure of a uniaxial mineral, thus confirming the determination of hexagonal symmetry made by measurements with the goniometer."

and submitted to an annealing process in a regular pottery furnace. The heat is applied gradually and also taken away gradually, so that about a week is consumed in baking and annealing the manufactured article. In the case of large wheels a process of "truing" comes next, which is not necessary in the smaller ware. The goods are now ready for the market.

It is the chemical nature of carborundum that excites the most interest. If chemically pure carbon and silicon were used in its production it would be white, but analysis always shows the presence of a small percentage of impurities, chiefly Fe_2O_3, Al_2O_3, CaO, MgO, etc. Neglecting these, the carborundum is a compound of silicon and carbon, uniting atom for atom, and is, hence, a silicide of carbon, represented by the symbol CSi. The percentage composition should therefore show a ratio of 12 parts of C to 28 + parts of Si. Analysis practically gives us this ratio, which we may otherwise write as 1 : 2.33 +. Several analyses give us three ratios respectively: 1 : 2.33 —, 1 : 2.24, 1 : 2.29. In these the carbon appears to be a little higher than the theoretical percentage demands.

Carborundum crystallizes in disc-shaped forms of the rhombohedral type. The basal pinacoid is prominent and twinning occurs. The lustre is brilliant adamantine. The specific gravity has been determined by Mr. Richards with accuracy, and for the green variety is about 3.12. The bluish variety is slightly less in density.

Only the heat of the electric arc seems to have any effect on this material, and it is entirely unattacked by the ordinary mineral acids. Even after prolonged treatment with HF and H_2SO_4, the loss in weight amounts to only a trifle. This is probably a loss of silica alone, which is in the compound as an impurity, and not silicon in combination. At red heat, in a current of oxygen for some time, its refractory qualities become again demonstrated; for it loses but a trifle in weight, and, as in the case of treatment with HF, we may attribute this to a loss of uncombined material; that is, some uncombined carbon burns off.

The method of analysis is by fusion with caustic or carbonated soda for some time. The entire mass becomes black, due to the fact that the compound is decomposed with the setting free of C and to the transforming of Si into silicic acid to unite with the

alkaline base. The carbon eventually burns off. As it is only burned off with difficulty, the most extreme degree of fineness must be obtained in the sample used.

There are other curious results obtained in the electric furnace beside the formation of the product which is the main subject of consideration of this article. For instance, there is a thin layer formed between the core and the main product which consists of carborundum mixed with free carbon. The curious fact is that this carbon has been converted to the graphitic form and has the soft, greasy feeling of graphite and soils the fingers readily. An outer zone beyond the layer of carborundum is thin and of lighter color. In composition it is the same as the main product, but probably owing to the comparatively low heat at which it has been formed, it does not crystallize, but is amorphous, soft and easily reduced to powder. Beyond this zone, and outside of all, is an almost unchanged portion of the charge, consisting of sand, coke and salt—the latter in a fused condition.

The equation representing the interaction resulting upon the passing of the current is $SiO_2 + 3C = SiC + 2CO$. This appears to accord with the theory recently advanced, that combustion at a high temperature results in the formation of carbon monoxide alone and no carbon dioxide. By figuring from the atomic weights, it will be seen that the proportions of the material found by experiment and experience to be proper for a charge, allow for a reasonable excess of C over what would be required by this equation but such as might be expected to be oxidized by the access of the air from without. The CO is ignited and burns during the entire operation in little jets here and there all over the top and sides of the furnace.

A disputed question about this new substance is its hardness. The difficulty in obtaining it lies in the brittleness of the crystals. Whether it is as hard or harder than the diamond remains to be positively demonstrated. But it has been already successfully used in polishing diamonds, although not found serviceable for the first rough treatment of the stones. It has a large application in glass grinding and cutting, the same amount of material doing much more work and acting more quickly than any abrasive now used. Wheels made from carborundum are used in grinding the necks of the Westinghouse incandescent electric light globes, and

unless these wheels grind from twelve to fifteen times as many globes as the emery wheels formerly used, they are returned marked "not good."

The industry is still in its infancy, the patent having been secured less than two years ago. The inventor has already been honored by a Columbian medal and by the medal and premium of the Franklin Institute of Philadelphia.

ABSTRACTS.

ANALYTICAL CHEMISTRY, BY E. WALLER, PH.D.

Mercuric Oxide in Analysis. Smith and Heyl (*Zts. f. Anorg. Chem.* vii., 82). On concentrating solutions of certain chlorides to a few drops and then adding HgO and drying out and then heating to volatilize excess of HgO and the $HgCl_2$ formed, a means for determining some elements was obtained. Zn and Mn work very well, yielding ZnO and Mn_3O_4. Cd requires special care, the $CdCl_2$ being quite volatile, and sometimes escaping before being acted upon by the HgO.

Ni gives good results if special care is taken. Co gives oxides of varying composition according to the intensity of the heat applied, so that this method is unsatisfactory.

Bi works well if the oxychloride is dissolved in a little HCl, then a slight excess of HgO added and it is then evaporated. If any black spots appear they must be moistened with HNO_3. Final heating to full redness gives pure Bi_2O_3.

HgO as a precipitant, separated Fe_2O_3 from Mn readily, and fairly well from Ni and Co. Not, however, from Be_2O_3, UO compounds or Al_2O_3. No satisfactory results were attainable in attempting to separate Zn from Mn by this method.

Vanadium in Caustic Soda. Robinson (*Ch. News*, lxx., 199) finds this impurity in soda by practically the same means as it was found in caustic potash by E. F. Smith (QUARTERLY, xi., 371). The amount found was 0.0376 per cent. V_2O_5.

Carbonated and Caustic Alkalies. Aslanoglou (*Chem. News*, lxx., 166). The titration of total alkalinity with methyl orange indicator, and in another portion, titration to neutrality with phenolphthalein indicator (bicarbonate) is condemned as untrustworthy. Wilson (*Chem. News*, *ib.* 209) finds this conclusion unwarranted if proper precautions are taken.

Alkalimetric Determination of Magnesium and Calcium. Hundeshagen (*Chem. Ztg.*, xviii., 445, 505 and 547). These earths are precipitated as phosphates, and after freeing from other salts by washing, the mixture of $MgNH_4PO_4$ and $Ca_3(PO_4)_2$ is dissolved in a measured amount of standard HCl. Then a measured excess of standard NaOH is added, and the NH_3 distilled off, which gives the measure for Mg present. Now, on adding methyl orange (or cochineal) and titrating back with standard HCl, the neutral point is where the $CaH_4(PO_4)_2$ and $MgH_4(PO_4)_2$ are formed. Allowing for the Mg compound the amount of Ca present may be calculated.

If ammonium-phosphomolybdate is suspended in water, and titrated with normal KOH solution, using phenolphthalein as indicator, 1 c.c. of normal KOH = 0.003077 P_2O_5.

Calcium Oxide in Quicklime. Stone and Schenck (*J. Am. Chem. Soc.*,

xvi., 721). Report of an investigation on the method by shaking with solution of sugar, filtering and titrating the lime alkalimetrically.

The sugar solution should be 10 per cent. 150 c.c. suffice for 1 gramme of the sample. The possible impurities of the lime have practically no influence. Gravimetric determination of the lime dissolved takes more time, and is no more accurate than alkalimetric titration.

The method given is: Pulverize the sample finely, add to 1 gramme 150 c.c. of a 10 per cent. cane sugar solution, shake for twenty minutes, filter, and titrate the clear filtrate with normal HCl.

Standardizing Permanganate. Roberts (*Am. Jour. Sci.*, xlviii). Iron deposited by electrolysis from an oxalate solution was used. The proportions used were 10 grammes ammonia ferrous sulphate, in 150 c.c. of water, to which was added 5 c.c of saturated solution of $K_2C_2O_4$ and a considerable amount of $(NH_4)_2C_2O_4$. A current of 2 amperes was found to be the best strength for the purpose.

Qualitative for Alumina. Neuman (*Monatshr. Chem.*, xv., 53). The mixed precipitate containing possibly Al, Fe and Cr obtained by $BaCO_3$. is boiled with $Ba(OH)_2$, filtered, and the filtrate acidulated with HCl and then precipitated hot with dilute H_2SO_4. In the filtrate from the $BaSO_4$ ammonia gives a precipitate if Al is present.

Test for Cobalt. Ball (*Chem. News*, lxv., 36). A little Co solution with a crystal of $Na_2S_2O_3$ affords a mass of "peacock green" color. The same can be produced by fusing $CoCl_2$ with $Na_2S_2O_3$ or adding crystals of $Na_2S_2O_3$ to an alcohol solution of the Co salt.

Nickel Determination. Schmidt (*Ber.* xxvii., 1624). The Ni solution containing considerable amounts of NH_4NO_3, receives the addition of ammonia until it shows a slight bluish color (too large an excess is detrimental). Then an *excess* of H_2S water is added, and the solution boiled while it is being added, when the NiS separates readily. Filter the solution while still hot, and wash with H_2S water containing NH_4NO_3, keeping the precipitate always covered with the H_2S water to avoid oxidation. Transfer the NiS to a weighed porcelain crucible, add ammoniacal $HgCy_2$, evaporate over a low flame, and heat up cautiously, finally giving it a strong ignition. Cool and weigh NiO.

Delicate Test for Copper. Sabatier (*Bull. Soc. Chem.* xi., 683). A drop of a solution containing copper, let fall into about 1 c.c. of concentrated colorless HBr, or a mixture of KBr crystals with saturated solution of H_3PO_4 gives a decided purple color, due to the formation of a cupric bromhydrate. With weak solutions of copper the tint may be lilac, but it is perceptible when the solution contains one part Cu in 30,000 of water. The sensitiveness of the ferrocyanide reaction is put at one atom in 800 litres, about one part in 12,000; that of H_2S as about twice as delicate, hence inferior to the HBr test.

References to former allusions to this test are given: 1877, Cresti (*Zts. Phys. Chem.*, xvi., 474). 1880 Endemann and Prochazka (*J. Am. Chem. Soc.* i., 525). 1889, Denigés, (*C. Rend.*, cviii., 568). The use of H_2SO_4 with a bromide, as recommended by the latter, does not permit the test to be made so delicate.

American Refined Copper. Keller (*J. Am. Chem Soc.*, xvi., 785) uses Hampe's method, (separation of most of the Cu by KCNS).

25 grammes of the sample are treated in a tall beaker with 200 c.c. of water, 45 to 46 c.c. of HNO_3 (1.21) and 25 c.c. H_2SO_4 conc. (if much Sb or Bi are present, more H_2SO_4 up to 100 c.c. may be necessary). Cover the beaker and heat until nitrous fumes are no longer given off, then dilute with 200 c.c. water. The temperature is brought to 40° C. and a current of SO_2 passed in. When red fumes disappear, the liquid becomes turbid. A few drops of HCl may be added to insure precipitation of Ag. After standing in a warm place for 24 hours, the solution is filtered into a 2 litre flask. It may contain Bi, Sb, As, Fe, Ni and Co.

The precipitate may contain Au, Ag, AgCl, Se, Te, $PbSO_4$, and traces of Bi and Sb.

To separate the most of the Cu from the filtrate, a standard solution of KCNS (1 c.c. = 0.05 Cu) is gradually added from a burette, while a current of SO_2 is being passed. An excess of KCNS should be avoided —it being preferable to leave a little Cu in the solution. Make up to the mark and mix thoroughly. Then allow the precipitate to settle, and filter off an aliquot portion (say 1800 c.c.) in which the elements other than Cu can be determined by the usual methods.

In calculating the volume of the solution the specific gravity of the $Cu_2(CNS)_2$ is taken as 3, and as 25 grammes Cu afford about 48 grammes of this salt its volume would be 16 c.c. The actual volume of the solution would therefore be 1984 c.c. on which the calculation must be based. The insoluble precipitate containing Au, Ag, etc., should be detatched from the paper, and the latter destroyed by fuming HNO_3, the excess driven off, and the residue digested with HCl. In the filtrate from the AgCl, Se and Te may be separated by hydroxylamine hydrochloride, and warming. Collect on a tared filter, and dry at 105° to 110° C. to constant weight. A satisfactory separation of these two elements has not been achieved by the author.

Arsenic in Commercial Copper. Gooch and Mosely. (*Am. Jour. Sci.*, xlviii). An amount of the copper (not exceeding 1 gramme) is dissolved in HNO_2, and then converted to $CuSO_4$ by evaporation with H_2SO_4 to strong fumes. Dilute to about 5 c.c. and wash into a small (50 c.c.) flask with about the same bulk of strong HCl. The entire volume should be about 10 c.c. Connect the flask by means of a bent pipette (which serves as a distillation tube) with a test tube containing HCl (1 : 1), which is partly immersed in cold water, add 1 gramme KBr and distil nearly to dryness. Rinse out the flask, introduce the distillate, and distil again after adding another gramme of KBr, receiving the distillate in water.

A little free Br appears in the distillate which is removed by addition of a little $SnCl_2$. Introduce the solution into the Marsh apparatus and collect the As by passing the gases through a tube which is heated. (Sanger apparatus) comparing the mirrors with standards.

Analysis of Galenas. Hannay (*Min. Jour.*, lxiv., 423). Dissolve $KClO_3$ in HNO_2 heat to 50° C. and add a weighed amount of the ore (finely pulverized) in small portions at a time. Evaporate to dryness, add pure Na_2CO_3 and a little water, and boil for a few minutes. Cool,

add $NaHCO_3$ and digest for 15 minutes. Filter off the solution (containing all the S as Na_2SO_4) wash the residue containing all the Pb as carbonate, dissolve and determine.

Arsenic Tests of the U. S. Pharmacopeia. Curtman (*J. Am. Chem., Soc.*, xvi., 580). The limit of Bettendorf's test ($SnCl_2$) was found to be practically at 0.03 mgm. of As in one c.c. The addition of a strip of metallic Sn and heating the solution is preferable except in the presence of Sb and Bi.

When metallic Sn is used, equal volumes of reagent and sample appeared to be best. AsH_3 once formed is not decomposed by $SnCl_2$.

The presence of HBr, HCl, H_3PO_4 or H_2SO_4 appeared to be without influence.

Tin and Antimony. Mangin (*C. Rend.*, cxix., 224). After treating an alloy containing Sn and Sb with HNO_3, a mixture of SnO_2 and Sb_2O_4 is left, which may be ignited and weighed.

This mixture of oxides is then put into a beaker with some HCl and a ball of pure Sn, and heated with stirring on the sand bath until the white oxides are no longer apparent. Sn dissolves, and metallic Sb. precipitates. This is filtered and washed (finally with alcohol) dried and weighed.

Weight of Sb multiplied by 1.262 gives the weight of Sb_2O_4. Deduct this from the weight of the mixed oxides. This leaves weight of SnO_2, which multiplied by 0.78667 gives weight of Sn.

Stannic Sulphide. Schmidt (*Ber*, xxvii., 2739). In the course of some experiments on the analytical relations of arsenic, a stannic sulphide absolutely white, was obtained, which was found to dissolve in $(NH_4)_2CO_3$ the more readily, when freshly precipitated. Separable by acidification. Attention is called to it as a possible source of error in using the $(NH_4)_2CO_3$ separation for As.

Volumetric for Gold. Franchesci (*Bol. Chim., Farmac.*, xxxiii., 35). $AuCl_3$ boiled with excess of $K_2C_2O_4$ affords metallic Au. 6.533 parts Au being reduced by the destruction of 8.3 parts $K_2C_2O_4$. The solutions used are: I. $K_2C_2O_4$. 8.3 grammes per litre. II. $K_2Mn_2O_8$ solution equivalent in strength to solution I. c.c. for c.c. A measured amount of solution I. is added to the Au solution and the excess of oxalate is titrated back by means of solution II.

Electrolytic Separations. Classen (*Ber.*, xxvii., 2060) gives a paper on this subject. He insists upon a careful regulation of amperage and voltage, the former being measured by the volume of gas evolved from 100 cm. of electrode surface (ND_{100}). Results in detail are given with oxalate solutions of Cu, Cd, Zn, Fe, Ni, Co, Hg and Sn, cyanide solutions of Ag, Na_2S solution of Sb, and HNO_3 solutions of Pb and of Mn, also some separations. For the separation of oxides and of Hg a Pt surface roughened by the sand blast is recommended. With most of the depositions 2 to 3 hours were found to suffice.

Electrolytic for Copper in ammoniacal solution. Oettel (*Chem. Ztg.*, xviii., 879). If Rudorff's suggestions are followed (dilute solution,

much NH_4NO_3 and weakly ammonical) quite a large variation in the strength of the current (0.07 to 0.27 amp.) is permissible.

Cl, Zn, As and small amounts of Sb have no influence under these conditions, but Pb, Cd, Hg, Bi and Ni are also precipitated with the Cu if present.

Electrolytic Separation of Mercury from Other Metals. Rüdorff (*Zts. F. Angew. Chem.*, 1894, 388). An amount of solution containing not over 0.2 grammes Hg should be used. Deposit by the action of 2 to 3 Meidinger elements over night. Separate from Cd in HNO_3 solution. From Zn, Fe, Ni, and Mn in H_2SO_4 solution (in the latter case not over 0.3 gramme Mn should be present). With Ni solutions, especial care is necessary to expel all traces of HNO_3 by repeated evaporation with H_2SO_4.

Electrolytic Determinations of Halogens—Iodine. Vortmann (*Monatsh f. Chem.*, xv., 280). On electrolyzing an alkaline solution, using a silver anode, the halogen unites with the silver. In a KI solution containing alkali and Rochelle salt, all the I was thus fixed on the anode. This must then be heated to dull red to decompose some Ag_2O_2 which forms. The silver anode must then be replaced by a platinum one, and the current passed for a time, to separate out Ag which has dissolved to small extent. Then the weight of both anode and cathode shows the gain due to the halogen.

Rare Earths. Rowland (*Johns Hopkins University Circular*, May 1894) reports that in the yttrium group he has found seven different elements designated provisionally as *a*, *b*, *i*, *d*, *h*, *n*, *c*, *k*; *a* is the principal element of yttrium; *b*, *i* and *d* are the principal ingredients of erbium; *d* is an impurity in some samples of yttrium; *h* occurs mainly in samarskite; *n*, *k* and *c* form a group intermediate between the yttrium and cerium groups.

The paper is criticised by Crookes (*Chem. News*, lxx., 81), the admission, however, being made that possibly fuller details than those contained in the preliminary paper may show the criticism to be unnecessary.

Qualitative Reactions of Ceria. Dennis and Magee (*J. Am. Chem. Soc.*, xvi., 656). In a paper on "Contributions to the Chemistry of Cerium," the authors give incidentally references to the qualitative tests. These are PbO_2 and HNO_3 Gibbs (*Am. J. Sci.*, [2] xxxvii., 352); $NH_4(C_2H_3O_2)$ and H_2O_2 Hartley (*J. Chem. Soc.*, xli., 202); NH_4OH and H_2O_2 *Lecocq de Boisbaudran* (*C. Rend.*, C. 605) also Cleve. (*Bull. Soc. Chem.* [2] xliii., 57); Strychnia, Pluggé (*Arch. d. Pharm.*, ccix., 558); Bi_2O_4 and HNO_3 Gibbs. (*Am. Chem. Jour.*, xv., 546). The delicacy of these reactions was found to be:

PbO_2 and HNO_3, 0.025 mgm. in 7 or 8 c.c.; Bi_2O_4 and HNO_3, 0.017 mgm. under the same conditions; $NH_4C_2H_3O_2$ and H_2O_2, 0.01 mgm. NH_4OH and H_2O_2, 0.005 mgm: Strychnia, 0.01 faint. To apply Boisbaudran's test (the most delicate) in presence of a large excess of rare earths, add very dilute ammonia until the first permanent hydroxide remains after shaking. Then add a couple of drops of H_2O_2 and shake well. An orange-red precipitate of ceria appears.

Separating Zirconia. Baskerville (*J. Am. Chem. Soc.* xvi., 475). On adding SO_2 solution *in the cold* to a neutral solution of ZrO_2 and boiling with excess of SO_2 the ZrO_2 was completely precipitated. If the solution is as acid as serves for the separation of TiO_2 little or no ZrO_2 is precipitated.

Titration of Vanadic Acid. Browning (*Zts. f. Anorg. Chem.*). An excess of $H_2C_4H_4O_6$ is added to the acid solution, which is then boiled until the V_2O_5 has been all reduced. The solution then receives an excess of $KHCO_3$, and when perfectly cold is treated with an excess of I solution of known strength. After standing until the blue color of V_2O_4 entirely disappears, the excess of I is titrated with As_2O_3 solution.

Chlorine in Saltpetre. Hellich (*Chem. Zeit.*, xviii., 485). Samples of saltpetre, which, when tested directly, gave a very slight reaction with $AgNO_3$, reacted strongly after deflagrating with pure sugar. The surmise is, that it is present as perchlorate. The method for detecting it consisted in fusing 10 grammes with 0.5 grammes MnO_2 until the mass assumed a uniform green color, dissolving in 50 c.c. of water, decomposing the manganate with 20 c.c. of dilute H_2SO_4, filtering and testing with $AgNO_3$.

Detecting Perchlorates. Gooch and Kreider (*Am. Jour. Sci.*, xlviii.). Evaporating the solution to dryness and fusing with anhydrous $ZnCl_2$ affords free Cl when perchlorate is present. Chlorides have no such effect. Chlorates if present, must be previously removed by evaporation with HCl.

Nitrate if present, must be destroyed by adding to the dry substance 2 c.c. of strong HCl solution of $MnCl_2$ and evaporating, repeating the treatment with HCl once or twice. The Mn is then precipitated out by Na_2CO_3, and the $ZnCl_2$ test applied as above.

Detecting Hyarochloric Acid. Villers and Fayolle (*C. Rend.*, cxviii., 1152 and 1204). In presence of much iodide or bromide, or both, a test is usually difficult and uncertain. A modification of the aniline test proposed by Denigés has been found satisfactory. The aniline solution is made with: 400 c.c. of saturated solution of colorless aniline with 100 c.c. of glacial acetic acid.

In a later communication (*C. Rend.*, *ib.* 1413) the authors recommend the use of a reagent composed of: saturated aqueous solution of aniline 100 c.c.—of orthotoluidine 20 c.c., glacial acetic acid, 30 c.c.

The liquid to be examined is brought to a bulk of 10 c.c. placed in a flask, 5 c.c. H_2SO_4 (1 : 1) added, then 10 c.c. of a saturated solution of $K_2Mn_2O_8$, and gently heated—the gases being conducted into 3 to 5 c.c. of the aniline solution contained in a test tube immersed in cold water. If HCl only was present in small quantity the solution turns blue, becoming rose color (rapidly if warmed).

If much HCl is present the coloration is nearly black—(possibly a black precipitate). HI if present is oxidized and does not pass over. HBr affords compounds giving a white precipitate if HCl is absent. If HCl is present, the HBr modifies the phenomena described for HCl alone, affording colored precipitates.

Separation of Chlorine and Bromine. Engel (*C. Rend.*, cxviii., 1263). Dissolve 1 to 2 grammes of the material in 150 to 200 c.c. of water, add 3 to 5 grammes ammonium persulphate, warm to 70° or 80° C. and pass a current of air, which carries off all Br, which may be collected in dilute H_2SO_3 solution in which solution it may be determined gravimetrically or volumetrically by means of $AgNO_3$.

Detecting Hydrobromic Acid. Villiers and Fayolle (*C. Rend.*, cxviii., 1265). If iodide is present, mix the solution with Fe_2Cl_6 (free from Cl) evaporate to dryness, and heat for one or two hours on a water bath to volatilize I. Nitrates must be absent. Then dissolve in water, precipitate out Fe by an alkali, acidify with HCl, and test with Cl and CS_2.

Determination of Iodine. Villiers and Fayolle. (*C. Rend.*, cxviii., 1332). The solution to be tested is placed in a stop-cock bulb with CS_2 and a slight excess of Fe_2Cl_6 solution (free from Cl) is added. On agitating the I set free is taken up by the CS_2. The CS_2 is run off and fresh instalments added until it comes colorless. The dissolved I is then titrated in the CS_2 by standard thio-sulphate.

Sulphur in Pyrites. Johnson (*Chem. News.*, xx., 212) avoids interference of Fe in precipitating $BaSO_4$ by the use of hypophosphite. His method is: Treat 1 gramme of pyrites with 25 c.c. HNO_3, let stand 15 minutes, add 1,5 grammes $KClO_3$, warm for 15 minutes, and then boil down to dryness on a hot plate, the flask being inclined (to avoid loss by spattering). Add 20 c.c. HCl and evaporate to dryness again. Add 20 c.c. HCl, boil down one half, add 50 c.c. of water, and filter. Make up filtrate and washings to 200 c.c. Add 1.5 grammes $NaPH_2O_2$ and heat to boiling. Add a slight excess of $BaCl_2$. Allow to stand 3 hours. If the supernatant liquid is then clear decant through a filter. Drop about 1 c.c. of HCl upon the precipitate in the flask—add 100 c.c. of water, filter and wash as usual. The filtrate and washings should amount to about 500 c.c.

A blank test should be made to determine the amount of sulphate in the reagents.

Sulphuric Acid in Crude Commercial Hydrochloric. Rürup (*Chem. Zeit.*, xviii., 225). Fairly accurate determinations can be made by measuring the volume of the precipitate of $BaSO_4$ in graduated tubes.

10 c.c. of the commercial acid is nearly neutralized with ammonia in a small beaker. It is then heated to boiling and poured into the measuring tube. 5 c.c. of boiling saturated solution of $BaCl_2$ are added, the tube stoppered, shaken for 2 minutes then left to settle 5 minutes, and the volume read off.

Silicon and Alumnium in Iron. de Koninck (*Stahl u. Eisen*, xiv., 138). Dissolve in HNO_3 or aqua regia, and precipitate by ammonia, or if Mn is present, by basic acetate method using $NH_4C_2H_3O_2$. The precipitate is filtered off, dried, and placed in a platinum boat, which is inserted in a combustion tube, and the Fe volatilized off in a current of HCl gas. SiO_2, Al_2O_3, possibly with TiO_2 or Cr_2O_3 remain, and can be separated by well known methods.

Silicon in Blast-Furnace Slag. Shimer (*J. Am. Chem., Soc.*, xvi., 501). When aluminous ores are fluxed with magnesian limestones, spinel ($MgAl_2O_4$) etc., is apt to occur in the slag, which is not decomposed by fusion with alkaline carbonates. Hence it is never safe to omit the treatment with HFl and H_2SO_4 on the silica obtained by evaporation. Even chilled samples may contain some spinel.

Volumetric for Phosphorus in Steel. Noyes and Frohman (*J. Am. Chem. Soc.*, xvi., 553). In the reduction and subsequent titration of the "yellow precipitate" the multiplier for the iron value of permanganate to obtain the phosphorus standard is variously stated. If the yellow precipitate is $(NH_4)_3PO_4$, $12MoO_3$ and the reduction causes the formation of an Mo_2O_3 compound, the theoretical multiplier should be:

(Fe standard $\times$ 0.01538 = P standard.)

Werncke, who is followed by Blair, gives the factor 0.01628.

Dudley and Pease give the factor 0.01724.

Doolittle and Eavenson give 0.0160.

Investigation showed that these discrepancies were chiefly due to the fact that the reduced solution readily oxidizes by contact with the air or by dilution with water, etc., containing dissolved oxygen.

If, however, the passage of the solution through the reductor, is preceded by some dilute sulphuric acid, that the air in the reductor may be mostly or entirely expelled, and the solution (sufficiently diluted) is passed slowly through the reductor, and followed up by the acid wash water without allowing air to enter at the top, and the solution is titrated at once, and *without further dilution*, the molybdenum is reduced to Mo_2O_3 and the theoretical factor above given is correct.

The presence of arsenic seems to have no appreciable influence.

Phosphorus in Coal and Coke. Norris (*Am. Inst. M. E.*, February 1894). Process similar to that of Lychenheim. (See QUARTERLY xv., 280). 5 grammes are weighed into a Pt dish and incinerated, this operation being hastened by a stream of O after volatile matter has burned off. Moisten with water—add 25 c.c. HCl and 2 to 5 c.c. HF. Heat until dissolved; add HNO_3 and evaporate to expel other acids, and then conduct the precipitation and titration by the Emmerton method.

Phosphoric Acid. S. W. Johnson (*J. Am. Chem. Soc.*, xvi., 462). The conclusions are summed up thus: "The citrate method only gives good results by compensation of errors, and under exactly defined conditions, which must be empirically determined. A procedure good for calcium phosphates is quite inapplicable to ferric and aluminium phosphates.

Again, the molybdic method when carried out rapidly at temperatures higher than 50° or as high as 65°C. in presence of trivalent iron, aluminum or manganese, gives results too high, and in presence of great excess of nitric acid may give results too low, unless the filtrates from the yellow precipitate are mixed with additional molybdic solution and further digested until no more precipitate can be thrown down."

Titration of Phosphoric Acid. Alkalimetric test on the "yellow pre-

cipitate" Kilgore (*J. Am. Chem. Soc.*, xvi., 765). The most accurate results were obtained by the use of the official (O.A.C.) molybdic solution (100 grammes MoO_3 in 417 c.c. ammonia of 0.96 Sp.Gr. poured into 1250 c.c. of 1.20 HNO_3) and a temperature of 60°C. for 4 or 5 minutes. Pemberton's method of working (See QUARTERLY xv., 156 and 379) gave a solution not sufficiently acid to avoid co precipitation of MoO_3, and the tendency to error from that source is increased by working at the boiling heat. The author's plan is: make the solution of the sample as directed (by O.A.C.). Take a portion of the solution corresponding to 0.2 gramme (or 0.4 gramme for insoluble) add ammonia until a precipitate just begins to form and dilute to 75 c.c. If not much NH_4NO_3 is present add 10 to 15 grammes of that salt. Filter the molybdate solution to be used bring the solution of the sample to 60°C add the molybdate, digest 4 or 5 minutes at 60°C. Filter as quickly as possible, using the pump. Wash 3 to 5 times by decantation, then transfer to the filter and wash with water until no longer acid, then titrate with standard KOH, and back with standard HNO_3.

Nitrogen in Nitrates, Nitro and Nitroso-Compounds. Krüger (*Ber.* xxvii., 1633). Modifications of the Iodblauer-Kjeldahl method. 0.2 to 0.3 grammes of the substance is treated in a Kjeldahl flask with 20 c.c. of water (or if insoluble therein, with alcohol), 10 c.c., of $SnCl_2$ solution and 1.5 grammes tin sponge. Warm to complete decolorization and solution of the Sn. Expel alcohol if it was used, cool, add 20 c.c. concentrated H_2SO_4, evaporate to strong fumes, and after cooling oxidize by addition of slight excess of $K_2Cr_2O_7$. From this point proceed as in the ordinary Kjeldahl process. Volatile compounds should be reduced by heating with $SnCl_2$ in a sealed tube.

Tests for Small Amounts of Nitrous and Nitric Acid. Lunge and Lwoff (*Zts. f. Angew Chem.*, 1894, 345). For qualitative tests, diphenylamin is the best. The reagent recommended consists of 0.5 grammes diphenylamin, 100 c.c. pure concentrated H_2SO_4 and 20 c.c. water. In well stoppered bottles this keeps a long time. The test is best made by pouring some of the reagent into a test tube, and then pouring in carefully the solution to be tested, and observing the zone between the two liquids. (Blue with nitrate or nitrite). For quantitative purposes the reagent is unsuitable. For those Griess's naphthylamin test (Ilosway's method with acetate) is preferred for nitrous acid, and the brucin test for nitric.

Supposed New Element. (*Chem. News*, lxx., 87). Lord Rayleigh and Prof. Ramsay believe that they have isolated a new gas from the atmosphere, of density about 19, with a spectrum differentfrom that of nitrogen. One method of preparing it is by passing electric sparks through air, confined over KOH solution, to remove N in the form of oxides, and then absorbing the surplus (?) oxygen by pyrogallate. Another method consists in removing oxygen by passing air over hot Cu and then removing N by passing the gas over heated Mg. It seems to be present in the air to the extent of ½ to 1 per cent. Prof. Dewar suggests an allotropic form of N.

BOOK REVIEWS.

WATER OR HYDRAULIC MOTORS. By Philip R. Björling. London, 1894. E. & F. N. Spon. 277 pages. 208 illustrations. $3 50.

This book disarms criticism by the disclaimer, in its preface, of its intention to trespass upon the field of theoretical hydraulic engineering, and is called by its author an introduction to hydraulic motors. The first five chapters discuss the usual forms of water-wheels in a vertical plane, with copious illustrations of typical forms and usual arrangements. There are a few calculations and some tables and empirical rules. The sixth chapter contains the fullest presentation that has yet appeared of the typical Pelton wheel, both in its simple form and in its more advanced type, with several nozzles. It is specially full on the methods of controlling the Pelton wheel, and, so far as known, presents a unique description of this valuable and useful type of motor.

The discussion of turbine-wheels occupies eight chapters, and covers the important questions of construction, regulation and mounting, in addition to the ordinary information as to the fundamental methods of laying on the water.

The chapters on water-pressure or hydraulic engines present a number of types which are not familiar to the American designer, although they have, most of them, been illustrated in other publications. The rotary motors are more unusual and give special interest to this part of the book.

By far the most valuable part of the book with the American reader is the series of chapters, covering nearly eighty pages, devoted to the hydraulic ram in its different forms, both as a water-pumping engine and as a motor for other purposes. This discussion gives unique value to the book, since, so far as known, it is not to be found elsewhere. The drawings present a variety of types unknown on this side of the water, and the text describes the application of the ram principle on a scale to which we are not accustomed. Some of the accessory apparatus is also most interesting and ingenious, as calculated to make the ram more self-dependent and automatic than in its simple and fundamental form.

The closing chapter, on the measurement of water over weirs, is a compilation and *résumé* of other well-known data.

The book is an interesting illustration of the tendency to record, for the use of students, those facts in construction and arrangement which the older mathematical text-books usually have refrained from giving. The result of the study of such literature in advance of an exhaustive theoretical investigation is to give the young man a clearer idea of the significance of the theoretical discussion, and also for the many cases where a theoretical investigation is made unnecessary or is inconvenient, the young engineer is enabled to choose between competing devices on the basis of his knowledge of the whole field of practice as presented in a book of this sort. Such books serve to train and develop the faculty of critical selection of method, which is one of the highest requirements in the engineer.—F. R. H.

PRACTICAL HINTS ON THE CONSTRUCTION AND WORKING OF REGENERATOR FURNACES. By Maurice Graham. London: E. & F. N. Spon. New York: Spon & Chamberlain. 1894.

This work is an elementary treatise on the system of gaseous firing as applicable to horizontal and inclined retort-setting in gas-works. Part I. discusses the construction of the regenerator-furnaces, dealing with material of construction, as fire-clay, fire-brick, clay, brick and iron retorts, mortar, cement, concrete, common brick, wrought and cast iron and the making of gas-tight joints. Methods of furnace construction, as foundations, footings, piers, arches, flues and chimney shafts.

The producer or gas generator is described, with illustrations of the various kinds, both horizontal and inclined. The producer is also described in detail, discussing the various parts and their special functions. The regenerators or chambers through which the waste gases traverse, imparting their heat to the cold air in adjacent chambers, are briefly described in principle and action.

The setting of the retorts, ties, backstays, etc., together with general remarks relating to the mechanical construction of these furnaces, concludes the first part.

Part II., Practical Hints on the Working of Regenerator Furnaces, gives the theory of working, with analysis of ordinary producer gas, directions as to drying the brickwork, starting the furnace, clinkering fuels and general management.

This book is 16mo in size, bound in flexible covers, and is convenient for the pocket. The paper and typography are of good quality. 131 pages, illustrated by fifty cuts. The size, 16mo, and flexible covers make it a very handy pocket book.

It is especially waitten for the benefit of furnace-men who have charge of the retorts, and is a simple and explanatory treatise that well answers its purpose.—J. S.

PRACTICAL INSTRUCTIONS IN QUANTITATIVE ASSAYING WITH THE BLOWPIPE. For the Prospector, Miner, and Assayer, and for Use in Colleges. By E. L. Fletcher, U. S. Army. New York: John Wiley & Sons. 12mo. 142 pp.

This book is designed as a simple, inexpensive work for prospectors, miners, and assayers and for use in colleges. Quantitative blowpiping posesses several disadvantages which are not generally balanced by the one advantage of easy portability of apparatus. Accurate results can undoubtedly be obtained from rich ores, and by combining the results of several tests, approximate results may be obtained from poor ores. Its principal use is for the prospector in districts far from an assay office. The operations, apparatus, charges, etc., are essentially those of the assayer, the apparatus being, of course, on a small scale; for instance, the furnace is seven-eighths of an inch high, and the source of heat is a blowpipe lamp. Great care is necessary in sampling, weighing, measuring, etc., and any error is multiplied by a much larger factor than in assaying.

Qualitative tests are given in some detail.—A. J. M.

BULLETIN OF ALUMNI AND COLLEGE NEWS.

THE NEW SITE.*

"On the 1st of July, the college completed the payment of $1,000,000 for the new site. To complete this payment, it was necessary for the college to borrow $200,000; but this debt will be liquidated shortly by legacies due the college or from other funds at its command, without interfering with its annual revenues. The college is to take possession of the new site October 1, 1894, at which time it is to give a purchase-money mortgage of $1,000,000 in final settlement. If the present site of the college sells promptly for as much as the trustees think it is worth, the college ought to receive from it enough to pay off this mortgage, and to meet the expenses of moving and fitting up the new grounds in temporary fashion for our occupancy. There will be many expenses, such as fencing, grading, and the like, which the college itself must bear. It is my earnest hope that the buildings to be erected there will come to the college, without exception, by gift. It was the good fortune of the committee on buildings and grounds to submit, in May last, a scheme for the development of the new site which commanded the unanimous approval of the trustees. The summer has been largely given to the development of plans for the buildings immediately to be erected. While it is hoped that the college can utilize for a time some of the buildings already on the new grounds, some new buildings are immediately necessary. We must have a fire-proof library into which to move our books, and we must have a fire-proof building in which to deposit our extensive and valuable scientific collections. These two buildings represent our minimum needs. In addition to these we ought to have at the outset a gymnasium, a dining-hall, and a chapel. Even with these buildings, we should have only a part of those which we could use advantageously from the beginning. We ought to have a building for the School of Arts, another for engineering, another for architecture, another for chemistry, and another for physics. Law and some other subjects will be accommodated temporarily in the library building. We ought to have a hall which should be the centre of the social life of the students, in which the literary societies could hold their meetings, the musical clubs, and all the many societies that make so large a part of student life in an American university. Then, there should be an academic theatre, so that the commencements may be held upon the grounds of the university itself. Naturally, all these things will not come at once. I have tried to indicate the order in which they seem to me to be needed. For the sake of clearness, I append a list indicating the probable cost of each building—the figures in each case being only an approximation.

"We need, then, as soon as we can get them, the following structures:

	Estimated cost.
Library,	$750,000
Natural Science Building,	300,000
Gymnasium,	200,000
Dining Hall,	150,000
Chapel,	200,000
School of Arts,	200,000

* From President Low's Annual Report.

	Estimated cost.
Engineering,	300,000
Architecture,	200,000
Chemistry,	200,000
Physics,	200,000
Society Hall,	250,000
Academic Theatre,	150,000

"I hope that some of those under whose eye this report may fall will feel both able and glad to contribute one or another of these buildings to New York's historic college. By general consent, the new site is unsurpassed in location by that of any university in the world. It is near the Grant monument and the new cathedral of St. John the Divine. Any one placing a building upon this site, in such a location, may be confident of a memorial at once enduring and useful, and one which will be before the eyes of the people of the United States almost more than any college building in the land. Every stranger that visits New York will certainly visit these heights to see the monumental buildings which will be clustered there; and the people of New York, in showing them to their friends, will become familiar with them, and their affection will dwell upon them as among the most important buildings that minister to their civic pride."

DEPARTMENT OF PHYSICS.

Since last June the department has acquired a considerable amount of new apparatus, and changes in the arrangement of the limited space at its disposal have furnished room for new experiments. By a removal of the apparatus cases in the electrical-room space has been obtained for construction of a dark-room for photometric and polariscope work. The electrical-room has been supplied with the street-current, thus permitting the duplication of many of the experiments. Adjoining the research-room, at the southern end of the top floor of Hamilton Hall, a large dark-room has been built, which has enabled the department to prepare almost all its lantern-slides and photographs, as well as to conduct several important photographic investigations. The department now gives laboratory instruction to the first-year medical students in addition to the theoretical and practical instruction to the students in the Schools of Mines, Arts and Pure Science. Medical students to the number of 250 attend the laboratory in four sections for half a year each. The apparatus and accommodations have been severely taxed, but the work has been carried on very successfully.

Under a new arrangement the students of the second year in electrical engineering attend the physical laboratory eight hours a week instead of six, as hitherto. The increased time will be spent in making a greater number of determinations and securing higher accuracy in performing all the experiments, while, during the second term, it is intended to give the students considerable work in standardizing and calibrating electrical instruments and to demand the greatest possible degree of accuracy and nicety of adjustment. The electrical engineers, and such other students as desire, attend lectures each week on Practical Methods of Physical Manipulation by Mr. Holbrook Cushman, while, beginning with the second term, new courses will be given on Higher Optics, by Prof. Hallock, and on Precision of Measurements, by Mr. Cushman. A course on the Practical Application of Electrical Measurements has been conducted during the year by Mr. H. C. Parker, and has been

well attended by advanced students in electricity and physics. Advanced work in spectroscopy is being done by four graduate students who are candidates for higher degrees, while the methods of physical instruction as given by the department are being carefully studied by a member of the faculty of a leading Chinese college. In all, some 370 students are engaged in laboratory work and attend lectures in the department, while 120 more are in attendance on lectures only.

Among the more important pieces of apparatus received during the past few months are the following: A large reading telescope, a Siemens wattmeter, two international ohms, a four-prism spectroscope, an opthalmoscope and schematic eye, six compound microscopes with test objectives and four sets of boiling-point apparatus.

Many lectures have been delivered by members of the department. Those of Dr. Hallock, before the Peabody Institute of Baltimore, were on the Modern Use of the Spectroscope and Prof. Langley's Investigations in the Infra Red Spectrum. Dr. Hallock and Mr. Gordon lectured in the series of Columbia College lectures at the American Museum of Natural History, while other members of the department have read papers before the New York Academy of Sciences and other scientific organizations.

In the line of investigation and research some important work is now in progress. Prof. Rood is completing an investigation of a new phenomenon of contrast and is also engaged with an investigation of the natural estimation of colors by trained and untrained observers. Prof. Hallock is working at a research on the use of the nasal cavity in singing and the behavior of the vocal cords in varying the pitch of a note. Mr. Gordon is at work on the spectral curves of colored surfaces. Mr. Parker is occupied with the determination of extremely high and low resistances. He is also attempting to determine electrically the homogeneity of metals, and with Mr. Wade is investigating constant standards of illumination. Mr. Wade is testing the sensitiveness of photometers. Mr. Curtis is busy with a series of photographical investigations, having completed a critical comparison of long- and short-focus lenses for landscape photography. Mr. Trowbridge has completed a study of the water-sphereometer and is now working on a new form of hygrometer. Mr. Iglehart is investigating a new method of measuring the velocity of sounds and is also studying the cause of the sounds heard in respiration.

DEPARTMENT OF BIOLOGY.

Professor Osborn reports that the zoological courses in the School of Mines and the opportunities for biological study have been contracting year after year by the pressure for time brought to bear on the time set aside for these courses by other departments of study. While the college is probably in a better position to teach zoology thoroughly and well than ever before, the opportunities for this teaching have been steadily reduced until now the only direct zoological work is carried on by Dr. Bashford Dean, to a class of thirteen sophomores. Biology has such important relations not only in geology and palæontology, but to chemistry upon its organic side, that it seems a great pity that its exclusion has gone so far. Undoubtedly the indirect advantages of biological teaching would be very great, and we look forward to the time when upon the new university site the main Biological Department and several of

the Natural Science Departments of the School of Mines will be brought more closely in connection with each other, and biology will be restored to its normal place in the curriculum of the School.

Dr. Bashford Dean has been vigorously carrying on his studies among the fossil and living fishes in the preparation of his volume, in the Columbia Biological Series. This is sure to be of great interest to the students of the School of Mines, since the work originated in Dr. Dean's studies under Professor Newberry on the fossil fishes. The volume will be profusely illustrated, many of the cuts being taken from types in the Geological Museum. The closing chapter upon the embryological development of the fishes will be largely made up of observations made by Dr. Dean himself, upon the Sturgeon and Gar-Pike, two types which he has succeeded in artificially fertilizing and hatching for the first time.

Department of Mining.

Very important additions to the equipment of the department have been made during the year. A number of large elaborate models of mines and mine equipment, aggregating a value of nearly $8000, were secured from among the exhibits in the Mines and Mining Building at the World's Fair. These models were presented by the exhibitors or purchased from a fund generously placed at the disposal of the department by Mr. F. Augustus Schermerhorn. The St. Joseph Lead Company presented a very elaborate model of their large dressing works at Bonne Terre, Mo., and the Copper Queen Mining Company gave two beautiful models in wood, exhibiting the methods of mining at Bisbee, Arizona. Among the models purchased was the entire exhibit of the Cleveland Cliffs Mining Company of Ishpeming, Mich., comprising two large models of their mines, and full-sized specimens of the timber used. A Shaw gas tester, an apparatus for determining minute percentages of fire-damp in the air of mines was purchased.

Electrical Engineering Department.

The number of students shows a steady increase each year, the total number pursuing the course in Electrical Engineering being over one hundred for the present year.

One interesting faet is that several students who have graduated in mechanical engineering at other scientific schools, have come to the School of Mines to study electrical engineering. It is possible for them by earnest work to obtain the degree of E.E. in one year, since they can devote their entire time to the purely electrical subjects, they being already well educated in the mechanical and general subjects.

Two of the graduation theses of the last class have already been published and arrangements are being made to publish the others, all of the theses being of special merit.

Several of the fourth-year class have already selected interesting subjects for their graduation theses and have begun work upon them. The teaching force of the department remains the same as last year, but their is now a laboratory assistant who takes care of and makes any necessary repairs or changes in the apparatus and machinery. This is found to work admirably and saves much time in the laboratory work and also greatly reduces the depreciation of the already large collection of valuable instruments and machines.

DEPARTMENT OF GEOLOGY.

At the close of last year Mr. van Ingen, who had been assistant in geology, was made curator of the geological collections. His work of revising the determinations of the fossils, and adding labels to those without them, has been continued. Much confusion has crept into these rich and varied illustrations of past life, and oftentimes gatherings from geological trips have been deposited without the necessary determinations. The verification of the labels, and the naming of those not so provided is a slow process, but it is proceeding as rapidly as possible, and is putting the materials in much more accessible condition for the systematic study of palæontology. For such extensive and valuable series of fossils we have long needed a permanent curator, trained in palæontology, and devoted to field work and collecting.

At the close of the college year Prof. Kemp and T. G. White, '94, made a trip along the north shore of the Great Lakes, via Niagara and Toronto, to the nickel district at Sudbury. After nearly a week in the mines, during which valuable collections were made of the ores and rocks, they proceeded to Port Arthur, and thence to Duluth and the Vermilion and Mesabi iron ranges of northeastern Minnesota. All the working mines were visited, and many valuable additions secured for the museum. From Duluth they went to the Penokee-Gogebic range, and repeated the same experience. Finally, the Summer School of Mining was joined at Houghton, and a week was devoted to field trips. During these, the party received many courtesies from Dr. L. L. Hubbard, the State Geologist of Michigan; from Prof. F. W. Denton, School of Mines, '89, recently of the Michigan Mining School; Mr. G. A. Marr the U. S. Engineer in charge of the local ship canals; Dr. Wadsworth, of the Michigan Mining School; and Mr. F. McM. Stanton, '87, Superintendent of the Atlantic Mine. No one of the party will soon forget the graceful hospitality of the last named, and to all some expression of our appreciation of their kindness is the least return that we can make.

On the journey homeward one squad came with Prof. Kemp through the Marquette range, stopping at Ishpeming, and visiting the Lake Angeline iron mine, and the Ropes gold mine. We were also shown about by Dr. W. S. Bayley, of the U. S. Geological Survey, to whose guidance we owed the opportunity of seeing some of the interesting features of the local geology. A day at Marquette spent on the peridotite of Presqu' Isle, and on the interesting diabase, felsites, and quartz porphyries of Lighthouse Point, with Mr. Seaman, of the Michigan Mining School, terminated the field work. July 26th, saw the party again in New York.

Prof. Kemp and Mr. Hollick attended the meetings of the American Association for the Advancement of Science and the Geological Society of America, in Brooklyn, in the early part of August, and each read papers before both societies. Prof. Kemp conducted a party of visiting geologists over the granite intrusions at Mt. Adam and Mt. Eve, near Warwick, Orange Co., which were described in No. XVII. of the departmental contributions, and Mr. Hollick took out three parties, one to the cretaceous clays and the glacial drift on the north shore of Long Island, one to the cretaceous deposits of the Atlantic Highlands, and the other to the terminal moraine on Staten Island.

August 1st Mr. van Ingen left for St. Johns, N. B., to collect Cambrian fossils for the museum, from the classic exposures of that vicinity. Our museum has been lacking in representatives of this period, and it was especially desirable to fill the gap. We were fortunate in having the interest and advice of Mr. G. F. Matthew, of St. John, to whose palæontological labors on the Cambrian rocks we owe a large share of our knowledge of these, the earliest of well preserved fossils. With W. D. Matthew, fellow in Geology, Mr. van Ingen camped for several weeks on the best exposures, and by the free use of dynamite, secured an unexpected richness of organic remains. Many new forms were brought to light, which are now being described by Mr. G. F. Matthew, and a very important series was obtained for our museum. In the last two weeks of the month, the party was joined by Prof. Kemp, and some time was spent on the igneous rocks as well, which will furnish the subject of the doctorate thesis of Mr. W. D. Matthew. Our sincere thanks are due Mr. and Mrs. G. F. Matthew for their great courtesy to us.

The larger part of September was spent by Prof. Kemp in studying the great magnetite deposits at Mineville, near Port Henry, and in further geological work in the neighboring Adirondacks. Assistance was rendered Mr. S. B. McKee, the engineer of the mines, in making a series of about twenty-five cross-sections, so that now a glass model, similar to the one which has been prepared by Prof. Munroe, of the Copper Queen mine, can be constructed for the museum.

In October, Prof. Kemp read a paper at the Bridgeport meeting of the American Institute of Mining Engineers, on the "Nickel Mine at Lancaster Gap, Penna., and certain Pyrrohotite Deposits in the Highlands of the Hudson."

The second edition of the *Ore-Deposits of the United States* appeared in November. The book has been much revised and enlarged.

Mr. Hollick spent about three weeks in July and August on Long Island, studying the phenomena of dislocation exhibited by the clays which underlie the terminal moraine. The trips extended to the end of Montauk Point, and into Gardiner's Island. The eastward extension of the yellow gravel formation was also traced, and the vicinity of Lake Ronkonkoma was visited with this object in view.

A number of days were also spent on Staten Island and in northern New Jersey, studying the cretaceous strata and collecting material.

Word has recently been received from Washington that Dr. Newberry's *Flora of the Amboy Clays*, edited, and completed subsequent to the author's death, by Mr. Hollick, is in the hands of the public printer, and may be expected shortly. Mr. Hollick has also been at work upon other manuscripts left unfinished by Dr. Newberry, and some of the most important material has been made the subject of biological and bibliographical papers before the Torrey Botanical Club, and the American Association for the Advancement of Science.

During June, July, and September, Mr. van Ingen was engaged in collecting fossils from the palæozoic exposures of central New York. By these labors the museum will be supplied with important additions.

Six Saturday geological excursions, and two on election day, have been offered this fall, one of which was prevented by rain. They have been well attended, and have proved a valuable adjunct to the teaching of the subject.

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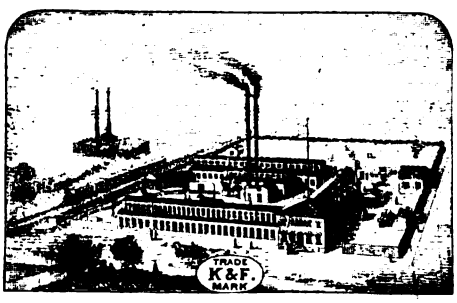

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THEORY OF ELECTROMETALLURGY.

BY FRANCIS B. CROCKER, E.M.

Introductory.—Electrometallurgy may be defined as that branch of science which relates to the electrical reduction or treatment of metals.

The subject may be divided into three important and quite distinct branches, as follows:

1. ELECTROLYTIC METALLURGY, which consists in reducing or separating metals by the decomposing effect which occurs when an electric current is passed through their compounds while in the liquid state. These compounds may be rendered liquid either by dissolving or fusing them; hence they are:

(*a*) Wet methods with *solutions.*

(*b*) Dry methods with *fused materials.*

Electrolytic metallurgy is applied to the following purposes:

(*c*) *Electrotyping*, which is the art of reproducing the exact form of type, medals or other articles by electrodepositing metal on the article itself or on a mould obtained from it.

(*d*) *Electroplating*, which is the art of coating articles with an adherent layer of metal by electrodeposition.

(*e*) *Electrolytic reduction of metals*, which is the art of obtaining metals from their ores or compounds by electrically decomposing such ore or compound in the state of solution or fusion.

(*f*) *Electrolytic refining of metals*, which is the art of eliminating

impurities by electrodepositing the metal itself, the foreign substances being left in the anode or liquid, or *vice versa.*

2. ELECTRICAL SMELTING, which consists in reducing metallic oxides by carbon at a high temperature produced by the passage of an electric current.

3. ELECTRICAL WORKING OF METALS, which consists in treating metals mechanically with the aid of heat generated by electric currents. Various mechanical processes which are facilitated by softening or fusing the metal may be effected in this way, the principal ones being: *welding, forging, rolling, casting.*

Historical Notes.—Immediately following the invention of the primary battery by Volta in 1800, Nicholson and Carlisle discovered the chemical action of the electric current in decomposing water.

In 1807 Sir Humphrey Davy gave his famous lecture "On Some Chemical Agencies of Electricity," he having, the same year, discovered the metals sodium and potassium by reducing their compounds electrolytically.

In 1834 Faraday * established definite laws and nomenclature for electrochemistry. From 1836 to 1839 Jacobi, Spencer, Jordan and Elkington applied these principles to practical use in the making of electrotypes. Since that time the science and art of electrometallurgy has made steady progress in electrotyping, electroplating, and in the production, refining and working of metals; but the advance has not been as great as might be expected, and several other branches of electrical engineering, such as telegraphy, telephony, electric lighting and electric power, have all far outstripped electrometallurgy in the extent and value of their results, in spite of the fact that the latter was the first practical application of electricity, and three out of the four other applications have been entirely developed during the last fifteen years. But in the opinion of those most competent to judge, electrometallurgy is certainly destined to become of enormous importance.

The physical and chemical principles and quantitative relations of electrometallurgy are more exact than those of almost any other branch of applied science, since the two most important electrical units—volt and ampere—are both directly based upon electro-

* *Experimental Researches*, Vol. I., pp. 195 to 258.

chemistry, the former being defined in terms of the E. M. F. of a Clark cell, and the latter being defined as the current which deposits .001118 grammes of silver per second. These definitions were selected by the International Electrical Congress, Chicago, 1893, as being the most reliable, which goes to show the accuracy and certainty of electrochemical science. Nevertheless, the general idea of electrometallurgy and electrochemistry is that they are vague and empirical; and most electrical engineers know very little of the theory or even the practice of these sciences, whereas they may be very well informed concerning the mechanical side of their profession.

It is, furthermore, a fact that the same laws and data which apply to electrometallurgy are equally applicable to electrochemistry, including not only the manufacture and treatment of chemicals electrically, but also the primary and secondary batteries. Thus we see the enormous importance of fundamental principles which underlie such a large part of electrical science, and which are, moreover, easily understood and applied.

The laws and data of electric heating, upon which the other branches of electrometallurgy are based, are also very definite, and these will be taken up and discussed after those of electrolysis.

It is assumed that the reader has a general familiarity with electrical terms, units and principles, and if not, he is referred to some elementary work from which he should obtain this knowledge before attempting to study any special branch of electrical science. Otherwise, it would be necessary to follow the too common practice of devoting the first half of each article or book to these same threadbare principles.

The principles of electrolysis are based on Faraday's law, which may be stated as follows:

The weight of material liberated by an electric current is directly proportional to the strength of the current and to the chemical equivalent of the given material. This at once establishes a fundamental and definite relation between electrical and chemical science. This principle is still further simplified by calling the weight in grammes of each element liberated by one ampere in one second (*i.e.*, one coulomb), its *electrochemical equivalent.* This enables calculations of the weight of metal produced by a given current and other such problems to be easily solved, but let us first consider the relation between the purely *electrical* quantities.

The electrical quantities in a circuit in which electrolytic work is being done are related in a manner which may be expressed by the following form of Ohm's law:

$$C = \frac{E - e}{R_g + R_1 + R_c} \qquad (1)$$

in which C is the current in amperes, E is the direct E. M. F. in volts of the dynamo or other source of current, e is the counter E. M. F, set up by the cell, R_g is the internal resistance in ohms of the generator, R_1 is the resistance of the conductors connecting the generator with the cell, and R_c is the resistance of the electrolytic cell itself. Each of these quantities can be predetermined or calculated even before the apparatus is made, or they can be actually measured by electrical instruments in the case of an existing plant.

The direct E. M. F., which must be produced by the source of current in any given case, is found by solving equation (1) with respect to E.

$$E = e + C(R_g + R_1 + R_c) \qquad (2)$$

If E be raised or lowered, the current will be increased or decreased respectively. In this way the strength of the current is controlled, the ordinary method being to vary the E. M. F. by regulating the value of the field magnetism of the dynamo. If either the counter E. M. F. or resistance of the cell (R_c) change, the current may be kept constant by regulating E accordingly.

The counter E. M. F. (e) may be calculated as follows:

The current, in passing through the electrolytic cell, produces a certain amount of chemical action in decomposing the material present. The principle of the conservation of energy requires that the electrical energy thus consumed must be equal to the chemical work performed, assuming for the present that the electrical energy is completely converted into chemical energy. Now we know that

$$\text{Electrical Energy} = c\ e\ t \qquad (3)$$

in which $c\ e$ is the product of the current and counter E. M. F.; that is, the number of watts used in doing the chemical work, and t is the time in seconds.

In chemistry the affinity or energy of combination of the various

compounds may be measured by the heat which is liberated when the combination takes; that is

$$\text{Chemical Energy} = w\ h. \tag{4}$$

w being the weight of the given metal or element in grammes, and h being the number of heat units produced when one gramme of this metal combines with the other constituent of the compound. The unit of heat is the gramme-calorie or heat required to raise one gramme of water one degree (Cent.) in temperature. Now from Faraday's law, we know that the weight of metal deposited by a given current is equal to the product of the current, the electrochemical equivalent of the metal and the time in seconds, hence

$$w = c\ a\ t \tag{5}$$

which, substituted in (4), gives

$$\text{Chemical Energy} = c\ a\ h\ t \tag{6}$$

This chemical energy must, as already stated, equal the electrical energy (equation 3) which liberates it; but since equation (6) gives the chemical energy in heat units, it is necessary, in order to equate the two values, to multiply the latter by the constant 4.2 to convert it into electrical units. This constant is the number of electrical units of energy (watt-seconds or joules) in one heat unit (gramme-calorie).*

By combining equations (3) and (6) we have

$$c\ e\ t = 4.2\ c\ a\ h\ t \tag{7}$$

and by cancelling out c and t

$$e = 4.2\ a\ h. \tag{8}$$

which is the expression for Thomson's Law, it having been enunciated by him in 1851.† It may be used for calculating the counter E. M. F. set up by a given electrolyte when it is decomposed by a current. It also gives the *direct* E. M. F. produced by a certain

* This constant is also given as 4.18 and 4.16, depending upon the specific heat of water and other experimental data. According to Rowland's determinations, 4.2 is correct at 10° C. See Everett's *C. G. S. System of Units*, page 98.

† *Phil. Mag.*, Dec., 1851.

chemical *combination*, as in the case of a primary or secondary battery.

Instead of stating the heat of combination in terms of one gramme of the given metal, the more modern method is to express it in terms of one *equivalent*. For example, the chemical equivalent or combining weight of zinc is 32.44, hydrogen being taken as unity, and the heat of combination of 32.44 grammes of zinc, with various other substances, are the values usually given in thermochemical tables. This is much more convenient and scientific, and enables direct comparisons and substitutions to be made, since each substance must always combine in exactly that proportion. In fact, by introducing this relation into equation (8), we can still further simplify it. Calling H the number of heat units produced by the combination of one equivalent, A, of the given material, then the heat of combination per gramme $h = \frac{H}{A}$ and substituting this value in equation (8), we obtain

$$e = 4.2 \frac{a}{A} H \qquad (9)$$

The ratio $\frac{a}{A}$, which is the electrochemical equivalent divided by the chemical equivalent, is a simple numerical constant, since these two equivalents are the same thing expressed in different units. This ratio is always equal to $\frac{1}{96410}$, or .00001038, which, substituted in equation (9), reduces it to the simple form

$$e = .0000435\, H \qquad (10), \qquad \text{or} \qquad e = \frac{H}{22938}$$

For the latter we may take without appreciable error the following very convenient formula:

$$e = \frac{H}{23000} \qquad (11)$$

In many cases the calculated E. M. F. (which may either be direct or counter) obtained by the use of equation (11) agrees almost exactly with that found by experiment, and in nearly all cases the disagreement is not more than a small fraction of a volt.

The values of H for various combinations can be found in many

electrical and chemical books. The data applicable to electrometallurgy are given in Gore's *Electrolytic Deposition of Metals*, pp. 39, 115 and 131.

A paper on the "Possibilities and Limitations of Chemical Generators of Electricity," by the writer (*Trans. Amer. Inst. Elec. Eng.*, Vol. V., p. 277), gives results of combinations of thirteen of the most important metals with chlorine, bromine and iodine, respectively, and the average difference between the calculated and determined values is not more than about one-tenth of a volt. The calculated E. M. F. of Daniell and other primary batteries also agree well with the actual value.* Nevertheless, in some cases the discrepancies are considerable. They are due to the fact that all of the energy of combination may not be converted into electrical energy, some of it being converted into heat, which appears in the cell; hence equation (11) is not strictly true, and it must be modified as follows:

$$E = \frac{H}{23000} - y \qquad (12)$$

in which y is the amount that the actual E. M. F. falls short of that which would be obtained if the conversion of the energy of combination into electrical energy were complete. It is also possible for the action to absorb heat, in which case the E. M. F. would be higher. Therefore we may have

$$E = \frac{H}{23000} \pm y \qquad (13)$$

The value of y may be deduced by considering the case of a reversible voltaic cell, which is caused to pass through a complete cycle of operations in the following manner:

A secondary cell at an absolute temperature, T, is charged with one coulomb, and assuming the internal resistance to be negligible, the energy required in joules is numerically equal to E, the E. M. F. The chemical action involves one electrochemical equivalent of the active materials, since the quantity of electricity is one coulomb; for example, one electrochemical equivalent of the positive metal would be reduced.

The temperature of the cell is now raised to $T + dT$, and its E. M. F. becomes $E + dE$. The action is then reversed, one cou-

* Everett, *C. G. S. System of Units*, p. 199.

lomb being discharged and the cell is brought back exactly to its original chemical condition, and, lastly, it is cooled to its original temperature, E, which completes the cycle. The electrical energy generated during the discharge is $E + dE$.

The increment dE must be due to the conversion of a certain amount of heat into electrical energy, since the temperature is the only condition which is different during the discharge.

We know, from the second law of thermodynamics, that whenever heat is transformed into any other form of energy, the efficiency of conversion is equal to $\frac{dT}{T}$

In the present case a certain quantity of heat, which may be designated (in joules) as q, is given to the cell, and a certain amount of electrical energy is produced; hence,

$$\frac{dE}{q} = \frac{dT}{T} \tag{14}$$

Let us leave, for a moment, the case of the cell whose temperature is purposely changed by adding or subtracting external heat in order to study the effects, and return to the ordinary cell, whose temperature changes are due to its own action.

It was stated, in connection with equation (13), that when a cell absorbs heat it tends to increase its E. M. F., in which case

$$E = Q + q_1 \tag{15}$$

Q being the heat of combination in the cell, and q_1 is the heat absorbed, both expressed in joules per electrochemical equivalent; hence

$$q_1 = E - Q \tag{16}$$

Now, since q_1 is the heat absorbed by the action of the cell, it follows that it corresponds to q in equation (14), which is the external heat given to the cell; therefore we may substitute the former for the latter in equation (14), and we have:

$$\frac{dE}{E - Q} = \frac{dT}{T} \tag{17}$$

or

$$E - Q = T\frac{dE}{dT} \tag{18}$$

This is called the equation of Helmholtz, and represents the amount that the E. M. F. may be less than or exceed that obtained by Thomson's law; hence it should be substituted for y in equation (13), which then becomes:

$$E = \frac{H}{23000} \pm T \frac{dE}{dT} \tag{19}$$

$\frac{dE}{dT}$ is the rate at which the E. M. F. varies with change of temperature, that is, the temperature coefficient of the cell, and it may be positive, negative or zero. If, in equation (18),

$$E - Q > o \tag{20}$$

the temperature coefficient is positive; that is, the E. M. F. rises with the temperature, but if

$$E - Q < o \tag{21}$$

the E. M. F. falls with increase of temperature; and if

$$E = Q \tag{22}$$

the E. M. F. is independent of the temperature, and Thomson's law, equation (11), is exactly fulfilled.

Hence, all that is necessary is to ascertain the effect of temperaperature upon the E. M. F. of a cell, in order to determine whether its actual E. M. F. will be higher than, equal to or less than that which is equivalent to Q, the energy of combination. Confusion or error might be introduced, because of thermoelectric or Peltier effects; but these should be guarded against. The correctness of equations (18) and (19) were proved experimentally by Jahn,* who directly determined the total heat produced by placing the entire cell and its circuit within a Bunsen ice calorimeter, thus obtaining the value of Q. He also measured E, the E. M. F., and then compared the value of $E - Q$, found in this way experimentally, with that obtained by determining the temperature coefficient and calculating $E - Q$ by equation (18). In most cases the results agree with remarkable closeness, considering the difficulty of making such measurements. Taking, for example, a Daniell cell, in which

* *Wied. Ann.*, Vol. XXVIII., pp. 21 and 491. 1886.

the reaction is $CuSO_4 + 100\,H_2O + Zn = ZnSO_4 + 100\,H_2O + Cu$, the E. M. F. was found to be 1.096 volts, which, at 23,050 gramme calories per volt (the value adopted by Jahn) corresponds to 25,263 calories; and $E - Q$ was calorimetrically determined to be + 208, whereas, by calculating it from the temperature coefficient (equation 18) $E - Q = + 214$. The agreement is almost perfect, and it may also be noted that the error in calculating the E. M. F. of this Daniell cell by equation (11), without considering Helmholtz's equation (18), is less than 1 per cent. In the case, however, of a silver chloride cell in which the reaction is $2AgCl + 100\,H_2O + Zn = ZnCl_2 + 100\,H_2O + 2Ag$, the value of E is 1.021 volts = 23,753 gramme calories, $E - Q = -2{,}330$ (observed) or $-2{,}574$ (calculated). In this case the E. M. F. is almost exactly one-tenth of a volt less than given by equation (11).

The probable explanation is that the physical work or heat of solution is much greater in the latter case; hence, the temperature coefficient and the correction required by the Helmholtz equation (equation 18) are more important factors.

In fact, if the action in a cell is purely chemical, and physical effects, such as heat of solution, production of gases, etc., are zero or insignificant, then the temperature coefficient is correspondingly small, and the last term in equation (19) may be neglected; whereas, if the heat of solution is great, or there is considerable generation of gas, then the temperature coefficient is usually large, and the E. M. F. may be 10 or perhaps 20 per cent. higher or lower than that given by equation (11).

The general principle is that the energy due to true *chemical* combination is practically all convertible into electrical energy, whereas the energy depending upon *physical* action, such as solution and change of state, is only partially convertible, being limited by the second law of thermodynamics as expressed in equation (14). The energy which can be transformed is called by Helmholtz "free," whereas the remainder, which must appear as heat, is designated as "bound" energy. The converse is also true; that is to say, the electrolytic cell is perfectly analogous to the primary cell in all its actions; and what is true of the direct E. M. F. of the latter applies to the counter E. M. F. of the former.

Actual Values of Counter E. M. F.—In considering counter E. M. F. in electrolysis, the mistake is often made of assuming that, whenever electrolytic action of any kind takes place, there is neces-

sarily a counter E. M. F. having a value of about one or two volts. As a matter of fact, the counter E. M. F. may be practically zero if no chemical work is done, as is the case if both electrodes are of the same metal and the solution remains of constant composition and density. In some cases the counter E. M. F. may be converted into a direct E. M. F., and aid the flow of current instead of opposing it. This would occur if the chemical action at the anode produced more energy than is absorbed at the cathode.

For example, if an anode of zinc be used in a copper depositing cell, the dissolving of the zinc forming zinc sulphate would give more energy than is required to decompose the copper sulphate and deposit copper on the cathode. In such a case of double chemical action the effect of each is determined separately and introduced in equation (1), which then becomes:

$$C = \frac{E - e_1 + e_2}{R_g + R_1 + R_0} \qquad (23)$$

in which e_2 represents the chemical action which aids the current, and e_1 the chemical action which opposes it.

We may have four possible cases depending upon the relations between e_1 and e_2.

First.—There may be simple electrolysis without secondary reactions, as, for example, when a solution of zinc chloride is decomposed by a current, the electrodes being of carbon, which is not affected by the action. In this case zinc is deposited upon the cathode and chlorine is set free at the anode, and there will be the full counter E. M. F. of about 2.11 volts.

Second.—An anode of silver is substituted for the carbon and the chlorine combines with the silver instead of being set free; consequently there is a chemical action aiding the current, the E. M. F. of which is 1.11 volts; hence, the resultant counter E. M. F. is $-2.11 + 1.11 = -1$ volt.

Third.—A zinc anode is now substituted for the silver, in which case the chemical action at the anode will balance that at the cathode, zinc sulphate being formed at one and decomposed at the other; hence, the counter E. M. F. is $-2.11 + 2.11 = 0$.

Fourth.—Finally, a magnesium anode is substituted, and the combination of the chlorine with this metal produces about 3.11 volts; hence the E. M. F. of the cell is $-2.11 + 3.11 = +1$ volt;

that is, it has become a direct E. M. F. instead of counter, and, therefore, aids the current.

Thus we may have, in these cases, values for the E. M. F. of an electrolytic cell varying from — 2.11 volts to + 1 volt.

In the third case, given above, the counter E. M. F. was stated to be zero, but, as a matter of fact, it has some value even when the two electrodes are identical. For example, a paper by W. J. Jenks on the well-known Edison electrolytic meter (*Transac. Amer. Inst. Elec. Eng.*, Vol. VI., p. 26), which consists of two zinc electrodes in a solution of zinc sulphate, contains diagrams showing the value of the counter E. M. F. It rises uniformly from .0009 to .0026 volt for a variation of current from 0 to 20 amperes (full load), the total surface of each electrode being about 8 square inches. The counter E. M. F. falls uniformly from .0034 to .0021 for a rise in temperature from 0° to 20° C. The compounds of copper and other metals usually exhibit a still higher counter E. M. F., when both electrodes are made of the corresponding metal, in fact zinc was selected by Edison partly because of its low counter E. M. F. when used in this way. The explanation of the cause of this phenomenon is probably the same as that of the value of the E. M. F. as given by equation (19) being due to the physical action (solution) which takes place. It may in some cases arise from the fact that the chemical action at the cathode is not quite equal to that at the anode.

The chemical actions in an electrolytic cell may not only consist of two reactions, but in some instances there may be three or more. In any case, however, the E. M. F. corresponding to each chemical action is found by equation (19) and the sum of all those which aid the current minus the sum of all those which oppose it is the actual value of the E. M. F. of the cell, that is:

$$e = \Sigma e_2 - \Sigma e_1. \qquad (24)$$

In order to know which actions aid the current and which oppose it, all that is necessary is to ascertain whether the action tends to generate heat or to absorb it, *i.e.*, is endothermic or exothermic. This fact is given in all thermochemical tables, but in general, combinations produce heat, and decomposition absorbs it. There are many exceptions to this rule, particularly in organic chemistry; but in the case of the simple metallic compounds, with

which we have to deal in electro-chemistry and metallurgy, the rule is practically universal.

Distinction Between Counter E. M. F. and Resistance.—The term "Polarization" is often used in electrochemistry and metallurgy; but it is unsatisfactory, except in the sense explained on page 118, since it has various meanings. For example, in connection with primary batteries, polarization signifies the effects produced by the liberation of hydrogen on the negative plate, which weakens the current both by counter E. M. F. and resistance, hence some "depolarizer," such as nitric acid, is used to combine with the hydrogen. In electrolysis the term polarization is often applied to the counter E. M. F., which is set up by the electrolyte, and sometimes includes the effect of the resistance of the cell, particularly if it is due to a poorly-conducting film on the electrodes. Any such vague or confused language is very objectionable and is partly responsible for the general lack of knowledge on this subject; the effects should be carefully separated and each called what it actually is.

It is, however, allowable to consider counter E. M. F. as an *equivalent resistance*, as is done in treating the action of self-induction in the case of alternating currents; but in electrochemistry or metallurgy it is better to consider it in its true nature, as it appears in equation (1). It is sometimes difficult to distinguish between counter E. M. F. and resistance; but, as a matter of fact, they are essentially different physical quantities. The latter always produces a *heating* effect $= C^2 R$, and the fall of potential which it occasions is directly proportional to the current, being $C R$. Whereas the counter E. M. F. rarely produces any heat (the single exception being the Peltier effect), since it represents the conversion of electrical energy into chemical, mechanical or magnetic energy, and its value is usually independent of the current strength; for example, the counter E. M. F. of a storage battery is practically the same whether the current is very small or has its full value. The best way to measure the counter E. M. F. of an electrolytic cell is to pass a current through it and then apply an electrometer or voltmeter to the terminals of the cell the instant the current is stopped; in fact, the instrument may be connected to the terminals before the supply circuit is opened, and the counter will then appear as a direct E. M. F. of practically the same value. An electrostatic or high resistance instrument should be used in order

that the current which it requires shall not drag down the E. M. F. and the reading should be made as quickly as possible. The counter E. M. F. may also be calculated by equation (2), if C, E and R are known.

The Resistance of the Generator.—(R_g) is the electrical resistance of the armature of a shunt-wound dynamo and the sum of the resistances of the armature and series field magnet coils in the case of a series- or compound-wound machine. In a primary, secondary or thermoelectric battery it is its internal resistance. The value of R_g should usually be between 1 and 5 per cent. of the total resistance of the circuit, which latter is $R_g + R_1 + R_c$.

It may be measured by some of the well-known methods; but ordinarily it is so low that the fall of potential or "drop" method is most applicable.* The resistance of the armature may also be calculated if the size, length and arrangement of the armature-winding be known or can be ascertained by examination.

The resistance of brush contacts is quite a serious factor in electrometallurgical dynamos, since the currents are usually very large. Assuming the brush contact to be .001 ohm and the current to be 1000 amperes, the loss of potential would be 1 volt and of energy 1000 watts, or 1⅓ horse-power, which losses are excessive, unless the machine is 100 horse-power or more. Large brushes of copper-wire gauze are used in order to make this resistance as low as possible.

The resistance of the line or conductors connecting the cell with the generator may also be measured by the "drop" method, or it may be calculated by the formula:

$$R_1 = \frac{Lr}{d^2} \qquad (25)$$

in which L is the length of the wire in feet, d its diameter in mils (thousandths of an inch) and r is the resistance of 1 mil-foot (a wire 1 foot long and 1 mil in diameter). The value of r for copper, according to Matthiessen's standard adopted by the American Institute of Electrical Engineers (*Transactions*, Vol. X.) is 10.35 international ohms at 20 degrees C., 11.57 ohms at 50 degrees C. and 12.82 ohms at 80 degrees C.

The measurements are expressed in feet and inches, since these are almost universally employed in England and America, the

* *Practical Management of Dynamos and Motors*, by Crocker and Wheeler, p. 90.

metric system being rarely used for electric wires or conductors of of any kind.

To determine the resistance at other temperatures add to or subtract from the resistance at 20 degrees, which is 10.35 ohms per mil-foot, four tenths of one per cent. for each degree above or below 20 degrees; for example, add two per cent. for 25 degrees and subtract two per cent. for 15 degrees.

This result agrees with Matthiessen's formula within a small fraction of one per cent. for temperature between 0 degrees and 100 degrees C., and is far simpler; it is also probably of equal if not greater accuracy, since the latest results show a linear relationship between the resistance and temperature of pure copper.*

The current capacity or maximum current density that it is allowable for a conductor to carry, varies from one ampere per 500 circular mils for copper wires one-tenth inch in diameter or thereabouts, to 1000 amperes per square inch for large copper bars; that is, $C = \frac{d^2}{500}$, or $C = 1000\,A$ respectively, d being diamter in mils and A being area in square inches. The much lower current density in the latter case is due to the relatively smaller cooling surface of large conductors.

The resistance of the cell or bath may be calculated by the expression

$$R_c = \frac{D\rho}{S} \qquad (26)$$

in which D is the distance between the electrodes in centimetres, S is the area of each in square centimetres, and ρ is the specific resistance of the liquid; that is, the resistance between the opposite surfaces of a cubic centimetre of it. The measurements can also be expressed in inches and square inches, provided ρ is the resistance of a cubic inch. This formula assumes that the plates are perfectly parallel, and that the current flows directly from one to the other without spreading and without any action on the sides of or back of the plates. If the plates are not parallel, D should be the *average* distance between them. If the current spreads, owing to the fact that the cross-section of the bath is larger than the area of the plates, then we may assume S to be a

* See paper by Kennelly and Fessenden, *Proceed. Internat. Elec. Cong., Chicago*, 1893, p. 183.

mean between the two; but this is only an approximation, particularly if there is considerable difference between the two areas, or the distance between the plates is very small or very great. If the action may take place from the back and sides of the plate, then the exact resistance is usually very difficult to calculate; but, with plates placed close together, about one inch apart, and having an area of one square foot or more, the resistance may be calculated by equation (26) as being that of the liquid actually between the plates, since comparatively little current would flow outside of this volume, even though the plates did not extend to the sides of the bath. If a plate is placed between two others and the current flows in both directions from the middle plate, then the resistance on one side is found by equation (26), and the combined resistance is one-half of that. In the same way, if there were two anodes arranged alternately between three cathodes, or *vice versâ*, then there would be four compartments and the combined resistance would be one-fourth of the resistance of each, and so on for any number.

The specific resistance of electrolytes varies greatly with the chemical composition, the strength of the solution and the temperature.

As a general rule, acids and alkalies are better conductors than neutral solutions; partly diluted solutions of acids or salts usually conduct better than concentrated solutions; solutions of chlorides, bromides or iodides are better conductors than those of sulphates, nitrates and carbonates; and fused salts conduct better than the corresponding solutions.

Sulphuric acid, diluted with water to the density of 1.25, has a specific resistance of .624 ohms per cubic centimetre at 16 degrees C.; this is about the minimum resistance not only of sulphuric acid, but of almost any solution at that temperature.

A saturated solution of zinc sulphate at 10 degrees C. (density = 1.422) has a specific resistance of 33.7; and about half saturated (density = 1.27), the specific resistance is only 28.5, which is about the minimum value. A saturated solution of copper sulphate at 10 degrees C. (density = 1.205) has a specific resistance of 29.3, which, in the case of this salt, is the minimum.

Temperature Coefficient of Electrolytes.—The resistance of solutions, as with all electrolytes, decreases rapidly with increase of temperature; in this respect this class of conductors are similar to

carbon and exactly opposite to the metals. The specific resistance of dilute sulphuric acid (density = 1.25), which was stated above to be .624 at 16 degrees is 2.31 at 0 degrees and .358 at 28 degrees C. This corresponds to a negative temperature coefficient of about 3 per cent., which is nearly eight times as great as the positive temperature coefficient of copper. The study of electrolytic conduction is extremely interesting and throws much light upon the nature of electric actions and molecular physics in general. The writer has observed, for example, that a solution of bromine in water is a good conductor, whereas bromine and water separately are very poor conductors. This is remarkable for the reason that bromine, being an element, would not appear to be capable of acting as an electrolyte, whereas in the case of a compound dissolved in water it is easily conceivable how it acts as an electrolyte and increases the conductivity. Another interesting case is that of stannic chloride, which is a liquid at ordinary temperatures, but is almost a non-conductor. Nevertheless, a solution of this salt in water is an excellent conductor. Exact data on the conductivity of aqueous solutions of various acids and salts may be found in *Physikalisch Chemische Tabellen*, Landolt and Bornstein, pp 103–106.

The conductivity of non-aqueous solutions, such as those of alcohol, ether, etc., have been investigated by W. Hampe,* who states that alcoholic solutions of cupric chloride, and of zinc or cadmium bromide or iodide, also zinc chloride or bromide dissolved in ether are all good conductors. Gore states, as the result of his investigations,† that "alcoholic and ethereal solutions of metallic salts are much less easily electrolyzed than aqueous solutions of the same salts." The objects which might be attained by the use of such solutions are the lessening of the tendency to oxidation and secondary reactions, which are likely to occur in the presence of water, as, for example, in the deposition of aluminum, magnesium, etc.

Fused electrolytes are usually good conductors; for example, fused lead chloride has a conductivity almost five times as great as that of the maximum value for sulphuric acid. This figure is stated by F. Braun,‡ who also gives the conductivity of various other

* *Jour. Chem. Soc.*, March, 1888, p. 211.

† *Proceed. Birmingham Phil. Soc.*, Vol. V., Part II., p. 371.

‡ *Pogg. Ann.*, CLIV., p. 161.

fused salts. Gore, in his work on *The Electrolytic Separation of Metals* (London, 1890, p. 91), gives a long list of melted compounds which he has electrolyzed. W. Hampe * also enumerates many salts which are "good electrolytes" in the fused state.

In recent years the Hall, Kleiner, Heroult and other processes have been applied successfully to the commercial production of aluminum on a large scale. The electrolyte employed in these cases is a fused compound of aluminum, such as cryolite.

In the Hall process alumina is *dissolved* in a bath of melted cryolite, the former being the actual electrolyte which is decomposed. This is precisely analogous to decomposing a copper compound dissolved in water, except that by the use of the *fused* solvent the oxidation of the aluminum, which would occur if water were present, is avoided.

Non-conducting coatings on electrodes often greatly increase the internal resistance of electrolytic cells. These insoluble coatings may in some cases almost prevent the passage of the current. They may be avoided either by using electrodes which are not affected by the action, by mechanically cleaning the plates, or by adding to the electrolyte something which will dissolve off the coating.

Weight of Deposit.—Having now discussed the relations between all of the electrical quantities in the circuit (equation 1), we may take up the consideration of the weight deposited by a given current or by a certain quantity of energy. As stated in the beginning, this is fixed by Faraday's law, which requires that

$$W = a\,C\,t \qquad (27)$$

in which W is the weight in grammes deposited, a, C and t having the same significance as before. One ampere deposits .001118 gramme of silver per second; hence by Faraday's law the weight of any other substance deposited will be proportional to its chemical equivalent: that is,

$$W = \frac{.001118\,A\,C\,t}{107.7} = .00001038\,A\,C\,t \qquad (28)$$

107.7 and A are, respectively, the chemical equivalents of silver and of the given material. These expressions involve the use of

* *Jour. Chem. Soc.*, March 1888, p. 211.

awkward decimal fractions and the second as the unit of time. It is more convenient in practical electro-metallurgy to consider the weight deposited in one hour, which in the case of silver is 4.025 grammes and equation (28) becomes

$$W = .03737\ A\ C\ N \tag{29}$$

in which N is the time in hours, $C\ N$ being, therefore, ampere hours. From this equation by transposition the current required to deposit a given weight in a given time is found to be

$$C = \frac{26.8\ W}{A\ N} \tag{30}$$

and the power in watts is

$$E\ C = \frac{26.8\ W\ E}{A\ N} \tag{31}$$

E being the E. M. F. employed (equation 1). In these expressions for the weight of deposit, all the quantities are easily and definitely determined with the exception of the equivalents a or A. To the electrician this is one of the most puzzling points in electro-chemistry. The chemical equivalent A of any element is the weight which is equivalent to one gramme of hydrogen in chemical combinations, hence:

$$\text{chemical equivalent} = \frac{\text{atomic weight}}{\text{valency}} \tag{32}$$

For example, 35.37 grammes of chlorine combine with one gramme of hydrogen to form hydrochloric acid (HCl), and since one atom of chlorine combines with one of hydrogen, the valency or ratio of the number of atoms is one. Hence both the atomic weight and the chemical equivalent of chlorine are 35.37. But it requires two atoms of chlorine to satisfy one of Zn and form zinc chloride ($ZnCl_2$), that is 2×35.37 grammes of chlorine combined with 64.88 grammes of zinc; therefore the atomic weight of zinc is 64.88, its chemical equivalent is $64.88 \div 2 = 32.44$, and its valency or combining value of each atom is 2. In the case of iron there are two compounds with chlorine: $FeCl_2$ and $FeCl_3$. The former, or ferrous chloride, is analogous to zinc chloride and the

chemical equivalent is 27.94, being one-half of 55.88, the atomic weight. But in the latter, or ferric chloride, the number of chlorine atoms are three times those of iron, hence the effective valency is 3 and the chemical equivalent is

$$55.88 \div 3 = 18.63$$

Strictly speaking, the latter compound is Fe_2Cl_6, since there are two atoms of iron in each molecule or group of atoms, and the total valency of iron is 4, one "bond" or unit of the valency being required to hold the two atoms together. The ratio of the number of atoms, however, is 3, which is the effective valency.

Thus certain elements are monads, having valency = 1 and chem. equiv. = atomic weight, such as sodium, potassium, silver, chlorine, iodine and bromine; others, such as zinc and oxygen, are dyads, having valency = 2 and chem. equiv. = $\frac{\text{atomic weight}}{2}$ while many others have two or more different valencies, with corresponding chemical equivalents (equation 32).

This matter is of the utmost importance in electro-metallurgy, both theoretically and practically. For example, copper forms two chlorides, Cu_2Cl_2 and $CuCl_2$. In the former the chemical equivalent = atomic weight = 63.18. In the latter the chemical equivalent = $\frac{\text{atomic weight}}{2}$ = 31.59. Hence the actual weight of copper deposited is *twice* as great when a solution of the former is electrolyzed, the current and time being the same. Similar facts apply to the case of other elements which form two or more kinds of compounds.

The equivalents of compound substances are similar to those of elements, being the proportions in which they combine. For example, the amount of the radical SO_4, which tends to be set free when a solution of copper sulphate ($CuSO_4$) is electrolyzed = $\frac{32 + 4 \times 16}{2}$ = 48, the atomic weight of sulphur being 32 and oxygen 16, and the valency of SO_4 is 2, since it would require 2 atoms of hydrogen to combine with it and form H_2SO_4. In other words, there is one equivalent = 48 grammes of SO_4 for each equivalent = 31.59 grammes of copper. As a matter of fact SO_4 is not a stable compound and it would either combine with the

anode to form a sulphate, or if that were carbon, and, therefore, not acted upon, the SO_4 would break up into $SO_3 + O$, the former combining with the water of the solution to form H_2SO_4 and the latter being liberated as a gas.

The atomic weights, chemical and electro-chemical equivalents, are given in almost every electrical or chemical book. The data for both elementary and compound materials may be found in *Gore's Electrolytic Deposition of Metals*, pages 126 to 129.

The actual weight of deposit is sometimes less than the theoretical amount, *i.e.*, calculated by equations (27) or (29). Indeed, some authorities even go so far as to deny the truth of Faraday's law. In the opinion of the writer the discrepancies can usually be explained and are no greater and often less than the modifications which have to be made in all laws on account of the conditions in each practical case.

The most serious cause which reduces the weight of metal deposited is the setting free of hydrogen in place of the metal. This, however, is perfectly covered by Faraday's law, since the apparent loss of metal is accounted for by the amount of hydrogen produced. The liberation of hydrogen is likely to occur: First, if the E. M. F. or the current density (amperes per square centimetre) is great; second, if the solution is weak, and third, if the metal has a great affinity for oxygen and decomposes the water, thereby setting free hydrogen. In regard to current density it is found that a certain value gives the best results as to the character and weight of deposit, and if this rate is exceeded there is a tendency to set free gas and produce a pulverulent deposit. If the solution is weak a similar effect is produced, since the compound becomes used up near the surface of the cathode and the current is forced to liberate hydrogen instead of the metal.

Another reason for loss of metal in electro-deposition is *local action*, by which the metal is dissolved after it is deposited. If, for example, free acid is put in the bath to increase its conductivity, as is often done, this tends to dissolve some of the metal deposited, and the weight finally obtained may be considerably less than that which the current actually produces. The tendency to local action is increased by lack of homogeneity in the deposit or bath, such as a greater percentage of acid in the lower part of the bath than in the top, or a different chemical composition in one part of the deposit, whereby a voltaic action is set up between different portions of the plate.

Hastening chemical action by electric currents sometimes produces peculiar results. If one cell of battery is generating current in an electric circuit, and another cell is added in series, then the current in amperes is doubled as well as the E. M. F., provided the internal resistance is insignificant, hence two cells produce four times the power of one. The explanation is, that the second cell causes the first to work and consume zinc at twice the rate of a single cell and also adds its own power.

In electro-metallurgy this principle may be utilized to hasten the solution of a metal or other action. Copper is not quickly dissolved by sulphuric acid, but, if it be used as the anode of an electrolytic cell containing the dilute acid, the solution can be effected with great rapidity by means of a large current, the weight dissolved being given by equation (29). The E. M. F. would be small, being only that required to overcome the resistance, since the combination of the copper would evolve more energy than the liberation of the hydrogen would consume, so that the E. M. F. of the cell would aid instead of oppose the current (equation 23).

Electrolytic Polarization.—It has been stated that the term polarization is not at all satisfactory when used in a general way, or when applied to the combined effect of counter E. M. F. and resistance. There is, however, one case to which it is applicable. This is when the direct E. M. F. applied to an electrolytic cell is less than the E. M. F. required to decompose the electrolyte. Under these conditions the current cannot flow, and the electrolyte is in a state of strain analogous to the polarization of a dielectric. In short, the electrolyte, although a conductor, acts as an insulator, since its counter E. M. F. is greater than the direct E. M. F. Electrolytic condensers can actually be made on this principle.*

Usually, however, a slight current passes, due to a sort of leakage. This may take place in two ways: first, by the action of free atoms or ions which circulate through the electrolyte or have been previously absorbed in the electrodes. For example, the presence of any free oxygen at the cathode or hydrogen at the anode would reduce the counter E. M. F. and allow a corresponding quantity of electricity to pass; or second, the formation of secondary compounds with the gases and other materials present may reduce the counter E. M. F. due to the electrolysis itself.

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* *The Voltaic Cell*, by Park Benjamin, New York, 1893, page 411.

Selective Electrolysis.—One of the most interesting and useful cases of electrolysis is that in which the E. M. F. applied to the cell is just sufficient to decompose a certain salt, but is not high enough to affect the other compounds which may be present. Under these circumstances the particular salt is electrolyzed and its metal is deposited, but the other materials remain in the solution. This method enables a mixture of the salts of several metals to be treated so that each metal is extracted separately. The E. M. F. is first regulated at a point above the counter E. M. F. of the most easily decomposed salt, but just below the counter E. M. F. of the next salt, and so on, provided, of course, the differences between the E. M. F.'s are sufficient. In a similar manner it is possible to remove from the bath certain impurities and leave the pure compound in the solution.

In order to ascertain the exact E. M. F. required for each step, it may be calculated by equation (19), it may be determined by separately testing each of the compounds present, or the mixed solution may be subjected to a gradually rising E. M. F. to find at what point each metal begins to be deposited.

Deposition of Alloys.—This is exactly the opposite of the preceding case, since it has for its object the deposition of a mixture or alloy of two or more metals in certain proportions, in which case the direct E. M. F. must be higher than the counter E. M. F. of any of the compounds.

The factors which determine the relative amounts of each metal deposited are, first, the difference between the direct E. M. F. applied and the counter E. M. F. of each constituent; second, the relative quantities of each metal present in the bath; third, the comparative resistance of the different electrolytes; fourth, the current density; and fifth, the velocity of migration of the ions.

The E. M. F. is a very important factor, since it has been shown that in selective electrolysis it entirely determines whether a certain metal is deposited at all or not. The relative quantities of the compounds would also largely affect the result, and if the solution contained very much more of one metal than another, it is obvious that the deposit would be chiefly composed of the former. It is also evident that if any one electrolyte is of very much lower resistance than the others, the current will tend to flow through and decompose the former. If two or more electrolytes are present in about equal quantities, the currents through the two would be

$$C_1 = \frac{P - e_3}{R_e} \text{ and } C_2 = \frac{P - e_4}{R_f} \qquad (32)$$

in which C_1 is the current, e_3 the counter E. M. F., and R_e the resistance in the case of one electrolyte, and C_2, e_4 and R_f of the other. P is the effective difference of potential.

The weights of each deposited is found by substitution for C in equation (27) to be

$$w_1 = \frac{a_1 t (P - e_3)}{R_e} \text{ and } w_2 = \frac{a_2 t (P - e_4)}{R_f} \qquad (33)$$

The resistances of R_e and R_f may not be due to complete chains of molecules of each electrolyte from one electrode to the other; they may in certain cases be merely the resistances of the last layer or layers of molecules, in which case P should be the potential between this point and the cathode, since the current in the rest of the liquid is indiscriminate or common to both electrolytes.

If the resistances of two electrolytes were the same, that is, $R_e = R_f$ then the ratio between the weights of the two metals in the alloy would be

$$\frac{w_1}{w_2} = \frac{a_1 (P - e_3)}{a_2 (P - e_4)} \qquad (34)$$

A test of a mixture of two electrolytes which have nearly equal resistances, the counter E. M. F. of each being known, would enenable the value of P to be found from equation (34), and also from (33) if the relative resistances were known. In the deposition of brass, which is very successfully carried out in the arts, the resistance of the copper and zinc solutions are, or could be made, approximately equal.

Chemical Purity of Deposit.—It is evident from what has just been said in regard to producing alloys that an electrolytic deposit is not necessarily pure, and the common idea that electrolytic copper is always very pure is quite fallacious. Copper could be produced electrolytically which might contain almost any impurities. It depends upon the E. M. F., the current density and the impurities present. Even from a perfectly pure solution of a copper salt, the metal obtained may contain hydrogen and oxide of copper, both of which affect its physical and chemical properties.

Physical Nature of Deposit.—It is usually found that a certain current density gives a compact, reguline deposit of metal and that a greater current density tends to produce a pulverulent deposit, whereas a lower current density is likely to give a crystalline deposit. The exact cause for the various differences is not fully understood, and is usually determined by experience, but probably the time during which the molecules have to arrange themselves is an important factor. When the molecules are slowly deposited the molecular forces have full effect and characteristic crystalline forms are produced, whereas at a moderate rate of deposit the molecular forces do not have full time to act and arrange the particles, hence the metal is deposited in a solid mass. At a high rate the particles are not properly laid down and a muddy or pulverulent deposit is the result. The exhaustion of the salt near the cathode is also a cause of imperfect deposit, as already stated in connection with the liberation of hydrogen. This last fact is probably the reason for the allowable current density being usually greater with the more soluble compounds.

The Principles of Electrical Heating.

These are extremely simple, being based upon Joule's law, the statement of which is:

The heat produced by an electric current is proportional to the square of the current, to the resistance through which it passes, and to the time that the current lasts, that is:

$$\text{Heat in joules} = C^2 R t = \frac{E^2 t}{R} = E C t \qquad (35)$$

$$\text{Heat in grm.-cal.} = \frac{C^2 R t}{4.2} = .24\, C^2 R t = \frac{.24\, E^2 t}{R} = .24 E C t \qquad (36)$$

From these expressions the heat can be calculated if any two of the three quantities—volts, amperes or ohms—are known. The time, t, is given in seconds, but it is usually more convenient in electrometallurgy to substitute 3600 for t which gives:

$$\text{Heat per hour in grm.-cal.} = 860\, C^2 R = \frac{860\, E^2}{R} = 860 E C \qquad (37)$$

These formulæ are not only true for the whole circuit, but also for any *portion* of it. If the resistance of any part or branch of a cir-

cuit, and the current flowing in that part or branch, are known, the heat can be determined. Ordinarily, the easiest and surest method is to measure by an ampere meter the current C supplied to an electric furnace, for example, and by means of a voltmeter find the difference of potential P between the terminals, then the heat per hour in gramme calories $= 860\ P\ C$. This can be done while the apparatus is working; the resistance, which is more difficult to measure and is very variable, need not be considered.

The temperature produced by a current in a conducting body is:

$$\theta = \frac{.24\ P C t}{W S} \qquad (38)$$

θ is the *rise* in temperature (degrees Cent.) in the time t in seconds, $.24\ P C t$ being the heat generated, W the weight in grammes, and S the specific heat of the body. This assumes that the action is adiabatic, no heat being lost, which would be approximately true if the time is only a few seconds or the body is well enclosed in a non-conductor of heat.

If the loss of heat is considerable, which is usually the case in practice, then the temperature rises until the heat produced equals the heat lost, when it becomes stationary. The heat lost by a body $= \theta\ K F t$, in which K is the heat conductivity of the substance with which the electrical conducting body is surrounded, and F is a constant depending upon the size, thickness and form of the surrounding substance. Hence

$$\theta K F t = .24\ P C t \text{ and } \theta = \frac{.24\ P\ C}{K F} \qquad (39)$$

The same expression can be used if the electrical conductor is exposed instead of being enclosed, in which case K is its emissivity and F is a constant depending upon its size and form.

Efficiency of Electrical Heating.—The remarkable fact in this connection is that the conversion of electrical energy into heat can easily be made *complete*. For example, when a certain amount of electrical energy is supplied to an incandescent lamp it is all converted into heat except a few per cent. which is given off as light, but even this produces heat in the walls of the room and could be immediately converted into heat by enclosing the lamp in an opaque box. In short, electrical or any other form of energy is

wholly transformed into heat ultimately, whereas it is impossible to completely transform energy into any form except heat. The most prominent case is that of the steam engine, the entire energy of which can be made to appear as heat by means of a friction brake, whereas only 10, or at most 15 per cent. of the heat generated by the coal under the boiler can be converted into mechanical energy. A certain amount of heat may be lost in an electric heating apparatus after it is produced, and this causes inefficiency. The electrical energy may also produce effects other than heat, such as chemical work, fusion, vaporization, etc., which reduce the amount of sensible heat.

In the production of aluminum, for example, by the electrolysis of a fused compound, a certain fraction of the electrical energy is required for the work of decomposition and the remainder is converted into heat, that is

$$\text{Heat produced} = .24\ (E - e)\ C t \qquad (40)$$

This heat keeps the bath melted in a very convenient manner; thus the electrical energy performs two functions and the process is both electrolytic and electrical heating.

In electric smelting the electrical energy is primarily converted into heat, which may be increased or diminished by the chemical action which occurs in the furnace. The reduction of metallic oxides by carbon usually absorbs heat, which in the case of alumina is very great and is considerable even with oxide of iron, hence

$$\text{Heat produced} = .24\ E\ C\ t - w_1\ h_1 + w_2\ h_2 \qquad (41)$$

w_1 is weight of metal reduced and h_1 its heat of combination per gramme, w_2 is weight of carbon required for reduction, and h_2 its heat of combination per gramme. If any heat is consumed in fusion or vaporization it should also be deducted.

In electric welding the electrical energy is all converted into heat, only a very small portion of this is absorbed as latent heat of fusion, and the remainder appears as sensible heat, hence equations (37) and (39) apply to this case.

The great advantage of electrical heating is that it can be applied exactly at the point where it is required.

GARNET AS AN ABRASIVE MATERIAL.

By F. C. HOOPER, Met. E.

Although the mining of garnet for grinding purposes in this country has extended back over a period of ten or twelve years, few, if any articles, have appeared on the subject in scientific papers. In Europe the mineral has been mined for a much longer time, and previous to about 1882 was exported to this country. At this date a very hard garnet in large quantities was found in the Adirondack mountains. As its qualities for abrasive purposes were far superior to the foreign article, it soon replaced the latter in our markets; in fact, since the development of this new mining industry the current of trade has set to and not from Europe.

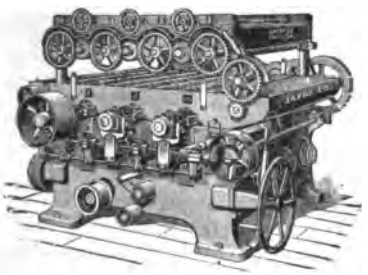
The mineral is found in a great many localities, but only in a few where it possesses the requisite hardness and occurs in marketable quantities. Dana gives the hardness of garnet as 6.5 to 7.5, and outside of a few localities—of which the Adirondacks is the principal one—this range of hardness will cover the different varieties of the mineral. Prof. Moses gives the following as the results of his tests on the Adirondack garnets: "Hardness over 7.5, very close to that of crystals of topaz; that is, 8.0, or a fraction under." This garnet, then, occupies an intermediate position as related to the hardness of quartz, 7.0, and that of corundum, which is 9.0. The garnet occurs in laminated pockets scattered through beds of a very compact hornblende-feldspar rock. The former mineral predominates, and often almost entirely replaces the feldspar. The size of the pocket varies from that of a walnut to those weighing as high as a thousand pounds. Most of the beds do not carry pockets that will average over five to six inches through. The existence of innumerable cleavage-planes prevents its use as a gem, but renders it most desirable as an abrasive material, affording sharp, cutting edges, even to the finest grades, when it is crushed and sized.

The total output of garnet in the United States for 1892 was about 2000 tons. The last two years very limited amounts have been mined, owing to the large stock in hand carried by the companies manufacturing garnet-paper.

After crushing and sizing the garnet, it is sold in bulk or put on

paper. The sizes of garnet put on paper vary about the same as flint- or sand-paper. The latter term is often applied to garnet-paper in the trades. The paper is put up in sheets or rolls of fifty yards.

FIG. 1.



Besides a number of miscellaneous uses, large amounts of garnet are used in the wood-working and shoe industries. For smoothing and finishing parts of wagons, buggies, cars, furniture, etc., the garnet-paper is placed on a variety of machines which have special adaptations. Fig. 1 shows the highest and best type of machines of this class, and is manufactured by J. A. Fay & Co., of Cincinnati, Ohio. It is designed for smoothing and finishing planed surfaces of wood requiring a high finish. There are the usual feeding rollers and three steel drums, upon which the garnet-paper is placed and graded according to the work to be done. The first drum carries a coarse grade of paper, the second drum a finer grade, for smoothing, and the third drum the finest grade, for giving the material a polished surface. Each drum has a lateral oscillating or vibrating motion, to prevent the formation of lines, which would result if the revolving motion was direct. The machines are made to use paper from 24 to 60 inches wide.

A cheaper class of machines, used very extensively in all kinds of wood-working factories for truing up and polishing any kind of soft or hard woods, are rapidly-revolving iron drums and discs for carrying the garnet-paper. They are made with a special but simple appliance for holding the paper. The drums are fixed to rapidly-revolving horizontal shafts, while the discs are placed at the end of a horizontal or vertical shaft. In front or around the revolving drum or disc a suitable support for the article to be smoothed is arranged. Another simple machine, and upon which a deal of garnet in bulk finds application, is the cotton belt. This

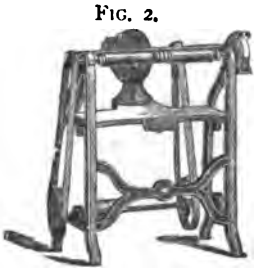
belt is four to eight inches wide, and its outer surface is covered with a thick layer of garnet held in place by a strong glue, and placed over two pulleys to run in a horizontal plane. The pulleys have a speed of 600 revolutions per minute and are placed from four to five feet apart. The belt between the pulleys presents a yielding surface, which is favorable to grinding rounded surfaces. An extra supply of belts are kept in stock to replace a belt when the garnet is all worn off its surface. The belt is renewed by applying alternate layers of garnet and glue, and thus allowing it to become perfectly dry before using again. Although crushed quartz or flint is much cheaper than the corresponding grade of garnet, the latter is preferred for the following reasons:

1. The garnet belt will smooth a given surface in less time than a flint belt.

2. The garnet coating lasts longer than a flint coating; hence there is a large saving of the labor required to repair the belts and in the amounts of glue and grinding material used.

The simplest class of machines are wooden pulleys or wheels, to which are fixed a leather or cotton belt covered with garnet.

FIG. 2.



In the boot and shoe factories garnet has become indispensable for the smoothing and "scouring" of soles and heels. In these industries the garnet is not used in place of the flint because it lasts longer, but on account of its giving a special finish not afforded by any other abrasive material. As in the wood working establishments we find two general types of machines are used.

One type of machine is shown in Fig. 2, as made by J. G. Buzzell & Co., of Boston. It consists of two rapidly revolving cylinders about ten inches long. These are covered with a thick felt, upon which the garnet paper is wrapped. The felt gives a yielding surface to the paper, which is very desirable in grinding. The small wheel on the end of the shaft is covered with a moulded

garnet-paper for "scouring" and finishing the heels. The paper for these wheels is moulded to grind any kind of a heel, from the straight-line heel to the extreme curve of the French type.

FIG. 3.

Fig. 3 shows the second general class of shoe-buffing or scouring machines, the belt type. A short horizontal paper belt, four inches wide, is carried on two small pulleys running 800 revolu-

FIG. 4.

tions per minute. The belt is prepared from rolls of garnet-paper by cutting the latter up into strips of the proper width and length and gluing the ends together. The cut shows a double belt machine, with fan and a heel-scouring wheel, as made by the Globe Buffer Co., of Boston. The heel-scourer, shown in Fig. 4, has two felt-covered wheels, to which the moulded paper is attached. The wheels are from 3½ to 7½ inches in diameter. This machine is also made by the last-named company.

SUGAR-ASH ANALYSIS.

By F. G. WIECHMANN, Ph.D.

The quantitative determination of the mineral constituents of sugar and of other saccharine products has claimed the writer's attion before;* but recent work in this direction would seem to warrant a brief recurrence to the subject.

The purpose of these lines is the suggestion of some alterations in the scheme of analysis given in the references cited, and, furthermore, the proposition of a specific form of report, in which form, it seems to the writer, the results of sugar-ash analyses can be most advantageously expressed.

For valuable assistance rendered in the analytical work in this connection thanks are due Mr. E. C. Brainerd.

The scheme of analysis is as follows: Weigh out 10 grammes of the sugar; dissolve in warm distilled water and filter to remove all suspended impurities. Wash the residue thoroughly with boiling water and evaporate the filtrate and the washings to dryness. Carefully carbonize the mass. Boil same with distilled water for one hour and filter. Wash the residue on filter with boiling water till nothing more can be extracted by this solvent.

Residue.—Dry, incinerate and weigh; record weight obtained as *insoluble ash.*

Filtrate and Washings.—Evaporate nearly to dryness in a platinum dish. Add some solution of ammonium oxalate and carry evaporation to dryness. Heat the dish and contents until the oxalates are completely decomposed. Then moisten with a solution of ammonium carbonate and again evaporate to dryness. Heat dish—but not above a dull red—until all ammonia is driven off. Cool in a desiccator and weigh. Enter weight found—of course, less weight of dish—as *soluble ash.*

The sum of the insoluble and the soluble ash represents the *total carbonate ash.*

Both the insoluble and the soluble ash are then dissolved in

* *Ash Determination in Raw Sugars*, The School of Mines Quarterly, Columbia College, Vol. XI, No. 1, p. 15. F. G. Wiechmann, *Sugar Analysis*, II. Edition, p. 79.

hydrochloric acid; these solutions are combined and evaporated to dryness. All of the chlorine is driven off, the residue is taken up with water and a little hydrochloric acid and filtered.

The insoluble residue on the filter, silica, is thoroughly washed, dried, ignited and weighed.

The washings are combined with the filtrate, ammonium hydrate is added and the solution is boiled and filtered. The precipitate, consisting of salts of iron and aluminium, is thoroughly washed on the filter, dried, ignited and weighed.

To the filtrate and the washings obtained in the foregoing, ammonium oxalate is added, and the whole is evaporated to dryness. The ammonia is burned off, and the oxalates are transformed into carbonates by adding some solution of ammonium carbonate, evaporating again to dryness and driving off the ammonia.

The mass is taken up with water, filtered, and the undissolved residue on the filter is washed; it is then dried, ignited and weighed, and consists of the carbonates of calcium and magnesium.

The washings are combined with the filtrate, placed in a weighed platinum dish and are then evaporated to small bulk. Some ammonium carbonate solution is added and the evaporation continued to dryness. The ammonia is then cautiously driven off—the dish must not be heated above a dull red—and the residue, after cooling in a desiccator, is weighed. This gives the alkalies, potassium and sodium, in the form of carbonates. If their individual determination is desired, this can be effected by changing them into the form of chlorides and proceeding as usual.

The quantitative estimation of the acids generally required in an analysis of this description—hydrochloric, sulphuric and phosphoric—are best made on a separate portion of the sample.

Ten grammes of the same are prepared as previously described. The carbonized mass, after being finely powdered, is boiled with distilled water and placed on a filter, is leached out with boiling water until there is no more reaction for chlorine by the argentic nitrate test.

The filtrate and washings are combined and made up to a known volume, 500 c.c. Of these, 50 c.c. are taken and the chlorine is determined volumetrically by a $\frac{10}{n}$ solution of argentic nitrate.

The carbonized residue which remains on the filter is dried, ig-

nited and dissolved in hydrochloric acid, and this solution is then made up to 250 c.c.

Next, a mixture is prepared consisting of 100 c.c. of the last-named solution and of 200 c.c. of the previously-mentioned solution—filtrate and washings combined—and divided into two equal portions measuring 150 c.c.

In one of these sulphuric acid is determined by the use of barium chloride, gravimetrically or volumetrically; the other portion serves for the estimation of the phosphoric acid by the molybdate and the ammonium-magnesium method.

Silicic acid has been found in the determination of the bases, and a determination of carbonic acid—should this be called for in an analysis of the ash—would, of course, embrace the carbonic acid which may have *existed* as such in union with some of the bases and the carbonic acid which *resulted* from the decomposition of other organic acids on incineration of the sugar or other saccharine product.

An interesting point brought out in the course of these investigations was that the alkalies were not all removed from the carbonized residue when the washings from the latter ceased to show the presence of chlorine.

In other words, in all instances the *soluble* ash found was to be *less* than the weight of the alkalies obtained, indicating that some of these were yet retained in the *insoluble* ash. This is clearly shown by the following analysis:

10 grammes of a syrup yielded:	
Insoluble ash,	0.096
Soluble ash,	0.229
Total carbonate ash,	0.325

The alkalies (potassium and sodium) weighed as carbonates 0.287 gramme, hence, exceeded the weight of the soluble ash by 0.058 gramme.

Another portion of this syrup was treated, and the insoluble ash obtained as indicated in the scheme of analysis cited. This insoluble ash alone was then dissolved in hydrochloric acid—the soluble ash being discarded entirely—and the usual process of analysis for the alkalies was followed.

The alkalies determined as carbonates amounted to 0.0576

gramme—that is, within four-tenths of a milligramme of the excess in weight above noted.

Another matter of interest noted was the form in which the iron and aluminium are precipitated by the ammonium hydrate.

Special determinations made to elucidate this point showed that in all syrup-ashes examined this precipitate contained phosphoric acid. The ashes of Java and Manila raw-sugars gave the same result.

As will appear later, it is a matter of importance to know the character of this precipitate, and, therefore this iron and aluminium compound should, after weighing, always be tested, at least qualitatively, for phosphoric acid.

* * * * *

The object of quantitative analysis is to determine as exactly as possible the composition of the substance examined, in this case the mineral matter occurring in sugar and in other saccharine products.

But here there are, unfortunately, difficulties to be encountered, which make the attainment of this object certainly impracticable, if not impossible; for in these products a considerable portion of the inorganic constituents exist in chemical combination with organic acids, and these organic acids are for the greater part destroyed or transformed by the process of ignition resorted to to secure the ash.

It is therefore evident that the composition of the *ash* of a sugar cannot in any way represent the constitution of the *salts* as they exist in the original substance.

Furthermore, it must be remembered, that the manner in which a sugar-ash is obtained will determine to a marked degree the results of the analytical showing; that is to say, a sugar-ash obtained by the "carbonate" method will, in some respects, differ materially from the ash of the same sugar when obtained by the "sulphate" method.

In view of these facts the *form* in which the analytical data obtained are expressed, becomes a matter of considerable importance.

Glancing through the German, French and English literature on the subject, it soon becomes evident that the greatest diversity of opinion exists as to the manner in which sugar-ash analyses should be recorded.

The following table will serve in illustration of this point:

	A. Cane-Sugar Ash.	B. Cane-Sugar Ash.	C. Beet-Molasses Ash.	D. Beet-Sugar Ash. III. Product.	Reference.
Calcium	CaO	$CaCO_3$	$CaCO_3$	CaO combined with organic substances or sugar.	
Magnesium	MgO	.....	$MgCO_3$	.....	*A.*—W. Wallace, Chemical News, Vol. XXXVII., p. 76.
Potassium	K_2O	K_2SO_4, K_2CO_3	K_2CO_3, K_2SO_4, K_3PO_4, KCl	K_2SO_4, KCl, $KNnO_3$, K combined with organic substances.	*B.*—Monier; Tucker Manual of Sugar Analysis, 1883, p. 223.
Sodium	Na_2O	Na_2SO_4, $NaCl$	Na_2CO_3	Na combined with organic substances.	*C.*—Frühling und Schulz, Anleitung der für die Zucker Industrie in Betracht kommenden Rohmaterialien, etc., 1885, p. 168.
Iron	Fe_2O_3	.....	Fe_2O_3	Fe	
Aluminium	Al_2O_3	Al_2O_3	Al_2O_3	Al_2O_3	
Silicon	SiO_2	SiO_2	H_4SiO_4	SiO_2	
Sulphur	SO_3	.....	.....	.....	*D.*—Ch. Violette, Journal des Fabr. de Sucre, 1873, No. 49.
Phosphorus	P_2O_5	.....	.....	H_3PO_4	
Chlorine	Cl	.....	.....	.....	
Carbon	CO_2	.....	.....	.....	

An analysis of a cane-molasses made by Avequin* records among the mineral constituents found, acetate of potassium, sulphate of potassium, chloride of potassium, bi-phosphate of lime, acetate of lime and phosphate of copper.

Analysis of the ash of sugar-beets yielded, according to the investigator,† insoluble silicic acid, soluble silicic acid, carbonic acid, phosphoric acid, chlorine, sulphuric acid, oxide of iron, lime, magnesia, potassium oxide, sodium oxide, rubidium.

It will hardly be necessary to cite more instances of the kind in order to illustrate the difficulties one would encounter should one attempt to draw inferences from or make comparisons between analyses recorded in such devious ways.

How, then, can these difficulties be overcome? Which is the best form of presenting analytical data of this description?

Analysis in instances of this kind can only determine the nature of the elements present and their respective amounts. It cannot yield information as to which of the different constituents are combined, nor in what proportions they may be grouped together.

Therefore it would certainly seem more logical to record that which we *can know* rather than that which we *fancy might be*, especially as every analyst, under the present circumstances, may give almost free rein to his fancy.

Therefore, the proposition of the writer, is the following:

Record all constituents determined as elements, and have the report specify the method by which the ash was obtained.

The following is a report couched in this form: analysis of a syrup ash.

	Per cent.
Total carbonate ash,	3.25

This ash consists of:

	Per cent.
Potassium, Sodium,	44.94
Calcium, Magnesium,	2.64
Iron, Aluminium,	0.20
Silicon,	0.89
Chlorine,	26.15
Sulphur,	1.16
Phosphorus,	Trace.
	75.98
Organic acids and non-ascertained,	24.02
	100.00

* N. Basset, *Guide du Planteur de Cannes.* Paris. 1889. p. 311.

† O. Vibrans, *Aschenanalysen der Bestehorn-Rübe. Zeitschrift des Vereins für die Reibenzucker—Industrie des Deutschen Reichs.* 1876. Vol. XXVI., p. 398.

If desired, the constituents bracketed in above report can be separately determined and so noted.

The last entry in the record, organic acids and non-ascertained, of course, includes all carbonic acid which may have been *originally* present in the syrup, which existed in the *salts* of the syrup, as well as that which was produced from the other organic acids through ignition of the sample.

It will hardly be necessary to call special attention to the various merits which this method of presenting results possesses.

The one objection which can be urged against its general adoption, and which seems entitled to consideration is, that the form of stating results here proposed and advocated, will make the results so given appear non-comparable with the data of earlier analyses.

But this is one of the very objections cited against the other modes of recording results, only, happily in this instance, the difficulty is easily removed. The following table* contains in its third column the factors by which the weight of the compound specified in the first column must be multiplied in order to obtain its equivalent in weight of the element named in the second column.

1	2	3	1	2	3
Al_2O_3	Al	0.529	Na_2CO_3	Na	0.434
$AlPO_4$	Al	0.221	Na_2O	Na	0.742
$CaCO_3$	Ca	0.400	Na_2SO_4	Na	0.324
CaO	Ca	0.714	P_2O_5	P	0.437
Fe_2O_3	Fe	0.700	H_3PO_4	P	0.316
$FePO_4$	Fe	0.371	SiO	Si	0.470
KCl	K	0.524	H_4SiO_4	Si	0.294
K_2CO_3	K	0.566	SO_3	S	0.404
K_2O	K	0.830	K_2SO_4	S	0.327
K_3PO_4	K	0.552	$Al_2O_3 + Fe_2O_3$	Al + Fe	0.634
K_2SO_4	K	0.449	$AlPO_4 + FePO_4$	Al + Fe	0.304
$MgCO_3$	Mg	0.288	$CaCO_3 + MgCO_3$	Ca + Mg	0.349
MgO	Mg	0.603	$K_2CO_3 + Na_2CO_3$	K + Na	0.509
$NaCl$	Na	0.394			

* Based on the Atomic Mass Table, revised by F. W. Clarke, October, 1891.

DETAILS OF MODERN WATER WORKS CONSTRUCTION.*

By WOLCOTT C. FOSTER.

Part III.—Valve-Pits and Valve-Boxes; Miscellaneous Valves and Stop-Cocks; Hydrants.

Valve-Pits and Valve-Boxes.

Where valves are likely to need much attention, and digging them up will be expensive and troublesome, they may be placed in pits or chambers. The most convenient and durable material of which to build these chambers will be found to be either stone or brick. They should have a suitable cover, preferably of cast-iron, and should be large enough to allow a man to enter and take the valve apart. Wooden pit curbs, though cheap, are not durable, while cast-iron ones are heavy and inconvenient to handle.

Usually, and especially with the smaller sizes of valves, it is not necessary to provide pits, the only requirement being to protect the exposed working parts and provide a means of easy access to the stem-nut, so that the valve may be opened or closed at any time. To serve this end, numerous forms of cast-iron valve-boxes have been invented. They are coated with a protective mixture the same as pipe, and are durable, economical and convenient.

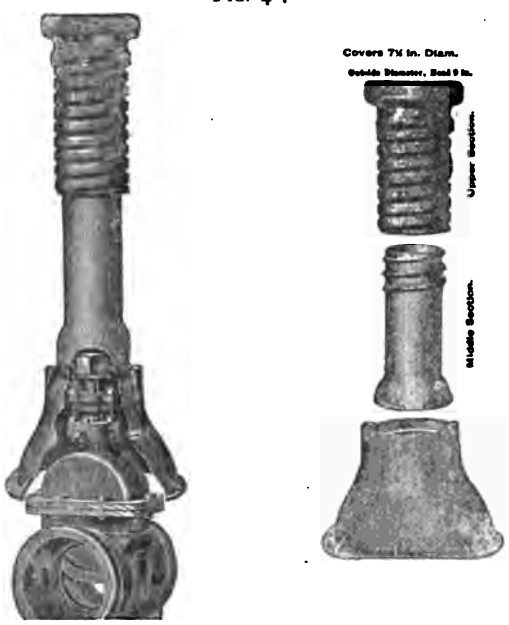
Fig. 41 shows one of the many forms of these boxes. The box may be lengthened by unscrewing the two parts of the stem. The size and style of the base depend upon the size of the valve. Fig. 42 shows several different styles of base. The length of the stem depends upon the depth below the surface that the pipe is laid. Should the ground be filled in over the pipe to such depth that the cover will be below the surface when the parts are unscrewed to their full extent, extension pieces (Fig. 43) can be inserted.

The shape of the covers should be such that they cannot be knocked out by a horse stepping on them or a wagon running over them without being locked in. Fig. 44 shows two shapes of

* Copyright 1895 by Wolcott C. Foster.

valve-box covers. It will be found that considerable trouble will be experienced in opening a box, especially in cold weather, where the cover is locked in place by tits on the side of the cover-

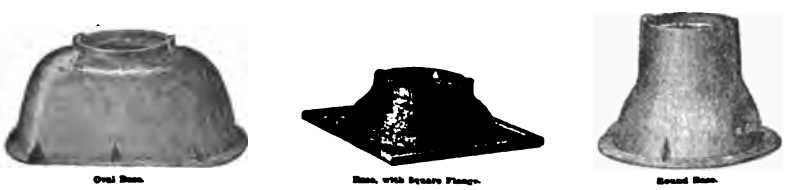
FIG. 41.



Bingham & Taylor Valve-Box.

chamber which fit into grooves in the side of the cover. To lock these covers they have to be turned part way around after having been put in place, and to unlock them they have to be turned

FIG. 42.



Bases for Bingham & Taylor Valve-Boxes.

back. In warm weather, dirt and gravel get jammed between the cover and the sides of its case, and the grooves become filled up, and in winter ice forms in these places and freezes the

cover fast, so that it becomes very difficult to turn it. Figs. 45 and 46 show two other styles of valve-boxes.

In setting valve-boxes the top should never be placed below the surface. Where pits are not built, valve-boxes should be used.

FIG. 43.

Extension Piece Bingham & Taylor Valve-Boxes.

FIG. 44.

Bingham & Taylor Valve-Box Cover.

Wooden valve-boxes, while cheap in first cost, rapidly decay, and will be found in the end to be more costly than iron ones.

MISCELLANEOUS VALVES AND STOP-COCKS.

In addition to the stop-valves used in the mains there are other contrivances for special purposes, such as air-valves, check-valves,

FIG. 45.

R. D. Wood & Co.'s Valve-Box.

FIG. 46.

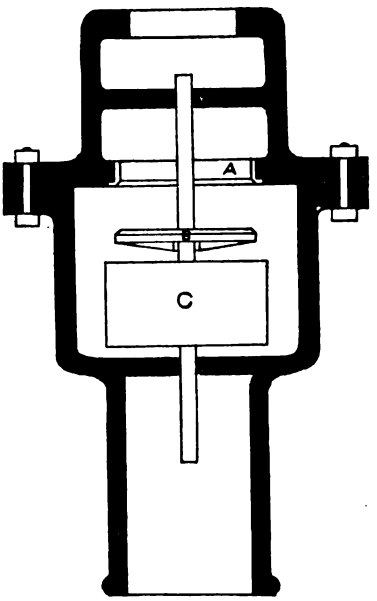
Ludlow Valve-Box.

foot valves, etc. The following is a short description of a few of the more important of these appliances.

Air-Valves.—Fig. 47 shows a valve which can be used when it is necessary to provide for allowing air to enter a line of pipe

while the water is being drawn off, and to permit air to escape while the pipe is being refilled with water. It is not designed to allow air that may accumulate at high points to escape while the

FIG. 47.



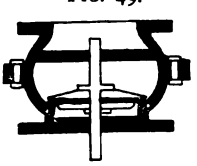
Air-Valve.

FIG. 48.

Air-Valve.

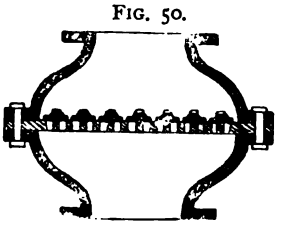
pressure is on the float, *C*. When the water lifts the float and closes the valve, it should remain closed while there is any pressure. The opening in the valve seat is 2 inches in diameter.

FIG. 49.



Vertical Check-Valve up to 8 inches in Diameter.

FIG. 50.



Vertical Check-Valve over 8 inches in Diameter.

At high points on a pipe line where air is likely to accumulate and obstruct the flow of water, a variety of valve, of which a form as made by one manufacturer, is shown in Fig. 48, may be used.

The valve is connected with the main through the opening by a piece of wrought iron pipe usually about 2 inches in diameter. The opening at *d* is about $\frac{5}{16}$ inch diameter. When air takes the place of water about the float, *b*, it drops, opening the small valve,

FIG. 51.

Horizontal Check-Valve.

FIG. 52.

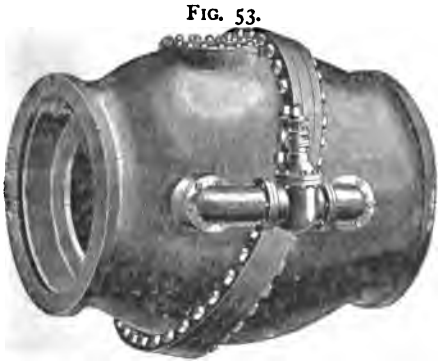
Horizontal Check-Valve with Secondary Gate.

d, allowing the air to escape. As the water returns it lifts the float closing the valve.

Check Valves.—Check valves are placed in pipe lines to allow the water to flow in one direction and to prevent its return and flow in the opposite direction. They are made for use on either vertical or horizontal pipe.

Fig. 49 shows a form for use on vertical pipe up to 8 inches

FIG. 53.



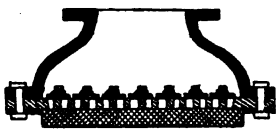
Large Horizontal Check-Valve with By-Pass.

diameter, and Fig. 50 for vertical pipe over 8 inches diameter. Fig. 51 shows a form of horizontal check valve, and Fig. 52 another form with a secondary gate which can open before the main gate. Fig. 53 shows a large horizontal check valve with by-pass.

Foot-Valves.—At the bottom end of pump-suction pipe it is usually customary to put a modification of the vertical check-valve,

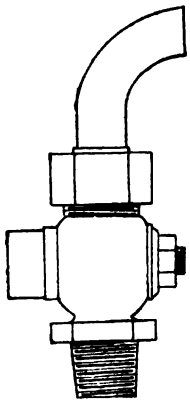
called a foot-valve, especially when the suction is a long one. Fig. 54 shows a form of foot-valve.

FIG. 54.



Foot-Valve.

FIG. 55.

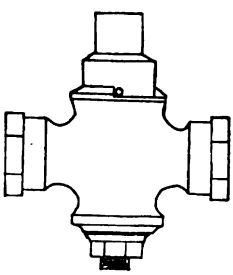


Corporation-Cock.

CORPORATION-COCKS, SERVICE-COCKS AND SERVICE-BOXES.

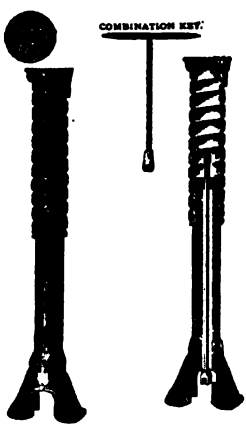
In making service connections of small diameter the service-pipe is usually connected with the main by a form of valve called

FIG. 56.



Service-Cock.

FIG. 57.



Service-Box.

a corporation-cock, of which one pattern is shown in Fig. 55. Just inside the curb-line it is customary to place a service-cock (Fig. 56) in the service-pipe, so that the water may be cut off at any

time that it becomes necessary. The service-cocks are protected and kept free to access by means of a cast-iron service-box, a form of which is shown in Fig. 57.

Hydrants.

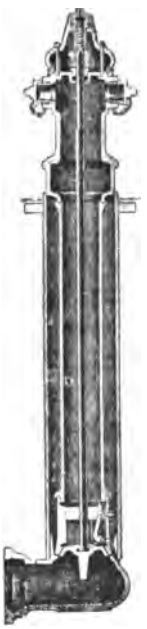
Hydrants may be divided into two general classes: fire-plugs and special hydrants for miscellaneous purposes.

Fire-hydrants or fire-plugs are of many forms and patterns;

Fig. 58.

Mathews Fire-Hydrant.

Fig. 59.



Gaskill Fire-Hydrant.

but, in general, may be subdivided into two kinds: those closing with the pressure and those closing against the pressure.

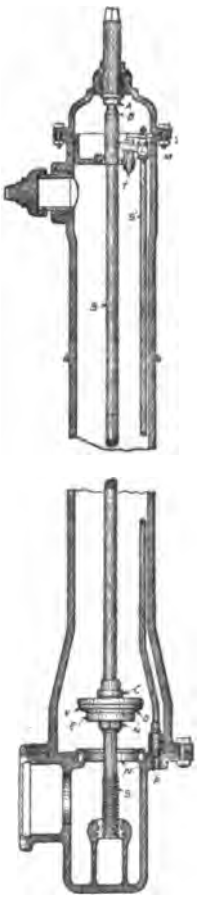
The principal requirements of any hydrant are that it should have ample water-way, so as to increase the friction as little as possible; that it should be simple in construction; that its parts should be easy of access and as few in number as possible; that it should be perfectly tight and quickly free itself from water after use.

A post-hydrant, or one extending above the surface of the

ground for about two feet or more, is the kind in most extensive use. They are usually placed just inside the curb-line.

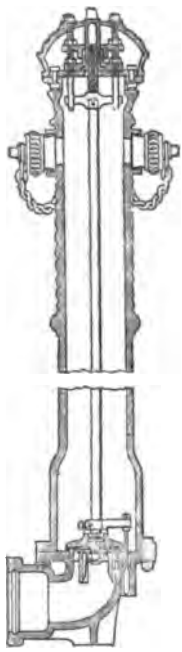
Fig. 58 shows a hydrant closing with the pressure, known as the Mathews hydrant. The valve revolves on the valve-rod and is made up of a number of leather washers turned to a conical

FIG. 60.



Eddy Fire-Hydrant.

FIG. 61.



Kennedy Fire-Hydrant.

FIG. 62.

Chapman Fire-Hydrant.

shape and held between two iron plates. To repair the valve the post is unscrewed and lifted out and the valve opened. For convenience in repairing these hydrants it is advisable to use an outside or frost case below the ground.

Fig. 59 shows another make of hydrant belonging to this class.

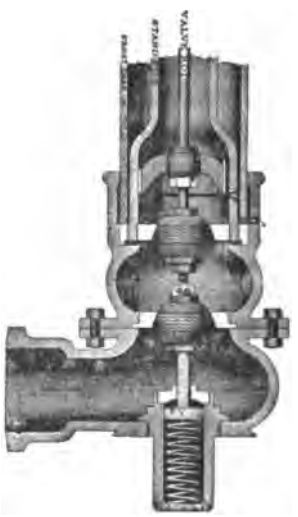
Fig. 60 shows a hydrant closing against the pressure, known as the Eddy hydrant. The valve is faced with a rubber gasket and can be removed by unbolting the top of the hydrant and lifting out the valve and valve-rod. The drip is positive-acting and closes before the valve opens and does not open again until after the valve is closed.

Figs. 61 and 62 show other makes of this class of hydrants.

FIG. 63.

Ludlow Fire-Hydrant with Secondary Gate.

FIG. 64.



Mathews Double-Valve Fire-Hydrant.

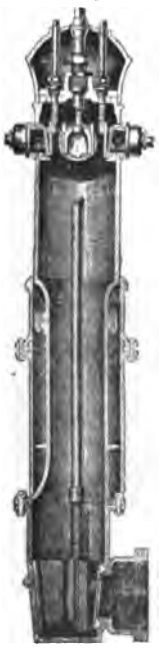
Hydrants open by turning either to the right or left as ordered. The nuts on top of the spindles are usually five-sided as well as the nuts on the caps of the nozzles. In ordering it is well to state the size of the nut desired, otherwise a collection of miscellaneous sizes is likely to result should more than one make of hydrant be in use.

The majority of hydrants used at the present time have two hose-nozzles. In large cities a large-sized nozzle for steamer use is frequently added. In ordering hydrants a hose coupling should

be sent to the works as a guide in cutting the nozzle-threads. The couplings vary in nearly every case, and there are now in use several hundred different patterns. Of course, the couplings in any one city should all be the same for the same diameter of hose.

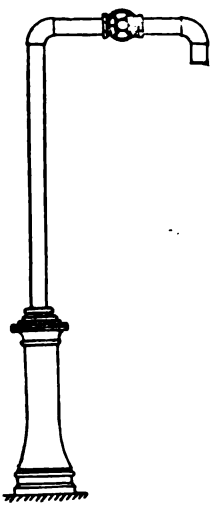
Whenever it becomes desirable to avoid shutting out a section of a water-supply system as much as possible a secondary gate-valve is placed in the supply-pipe connected with a hydrant at the

FIG. 65.



Chapman Fire-Hydrant with Secondary Gates on each Nozzle.

FIG. 66.



Crane Hydrant.

foot of the hydrant, as shown in Fig. 63. In such cases the hydrant has a flanged opening at its foot and the valve has a flange on one end, so that the two may be bolted together. With such an arrangement a hydrant may be easily repaired or removed without inconvenience to any of the consumers by merely closing the secondary gate. It is always advisable to use such an arrangement where hydrants are located on the main supply-pipe of a system, though it is not so essential on the smaller mains of the general distribution system.

Fig. 64 shows the lower part of a Mathews double-valve hydrant. This hydrant is intended to answer all the requirements of hydrants with secondary gates. It is made with two main valves, one placed above the other but disconnected. The lower valve closes automatically when the upper valve is closed, and allows the hydrant to be removed for repairs. Should the upper valve be injured it can be removed, and by leaving the valve-rod in place the lower valve can be operated with it while the upper valve is being repaired. The taking out and replacing of the hydrant is done in precisely the same way as with the ordinary hydrant of this make.

Good practice requires that not more than one hydrant be placed on a 4-inch main, and then it should be as close to the end connected with a main of larger diameter as possible. Whenever it can be done, a 4-inch main should receive a supply from both ends and should not be over 1000 feet long; if shorter, so much the better. Many engineers do not recommend placing any hydrants at all on four-inch mains, but make six-inch mains the minimum diameter to supply hydrants.

Hydrants with a secondary gate placed on each nozzle, as shown in Fig. 65, are also in use and have the advantage of allowing lines of hose to connect with or disconnect from multiple nozzle hydrants while one or more streams are being used without necessitating the closing down of the hydrant.

In placing hydrants in the ground care should be exercised to see that they are well set, that the drip is free and is not liable to be clogged up and that there is good drainage to carry away the water after shutting down.

For filling street-sprinkling carts and similar purposes a crane-hydrant will be found much more convenient than the use of a fire-hydrant, and in many cases will considerably reduce the hydrant repair bill. Fig. 66 shows a form of crane-hydrant. Provision should be made for shutting off the water below ground and also for draining the hydrant, so that it will not freeze in cold weather.

There are many forms of hydrants for miscellaneous and special uses; but as they have a much narrower application than the classes which have been described they will not be taken up.

A PLUMBING METHOD FOR STEEP SHAFTS.

By R. G. BROWN.

THE following method, while applicable to shafts of any pitch, is particularly useful in cases where the angle of inclination is but a few degrees from the vertical; for these the ordinary plumbing methods, on the one hand, are not suited, and, on the other hand, the transit is particularly unsatisfactory, owing to the large vertical angle and the consequent extreme perfection of adjustment and manipulation required for accurate results. The method is also very useful in checking transit work in inclines of all angles.

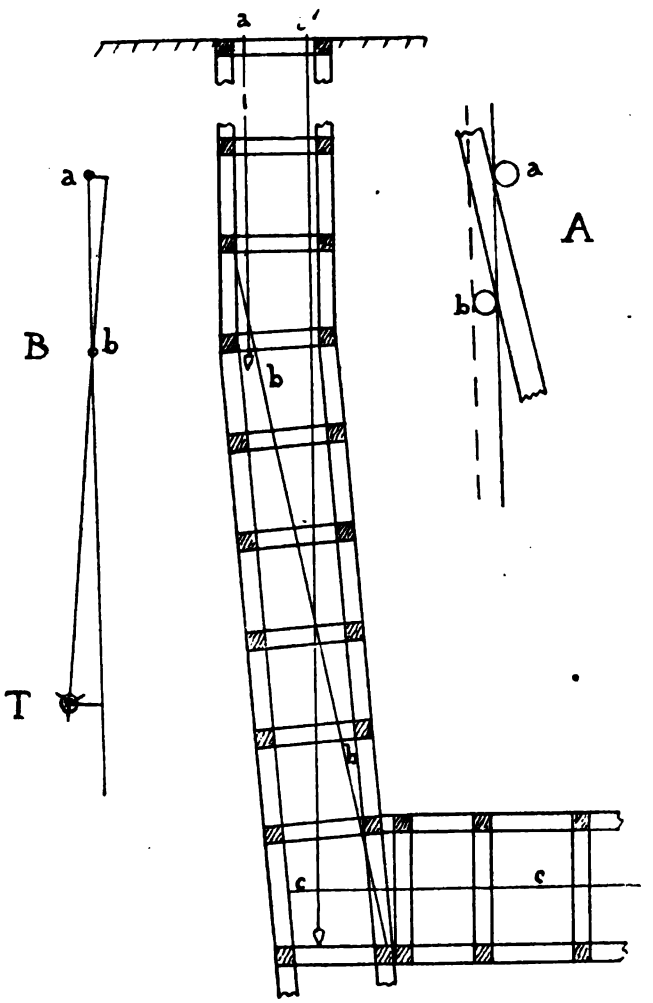
There is a fundamental difference in the methods of shaft work by transit and by plumb lines, although the aim is the same, namely, the establishing of underground bearings.

The transit accomplishes this by reading angles between courses, and a calculation of results, as in ordinary horizontal work; the plumb-lines transfer the shaft meridian from the surface to the underground workings, establishing meridians for every level, exactly under the surface shaft meridian. The transit work is then the more general, for it will be seen at once that plumbing methods are not applicable to shafts of such irregularity as to allow, in no direction, the passing of a plane—of as irregular boundaries as you please, clear of interference to the bottom. Or, to put more clearly a matter that is as simple to the mind as it is tangled to the pen, shafts that when viewed in projection from the surface, through the transparent earth, will not permit of the drawing of a straight line on that projection from top to bottom, and entirely within the sides. When such cases confront him, the engineer must pick out his best courses and pin his faith to his transit.

So much for preliminary.

Starting with an established meridian through the collar of the shaft, and assuming the specific case of the appended sketch, the method will be as follows: Carry the meridian down to the bend in the shaft by two plumb-lines (a', a), suspended in the meridian at the collar of the shaft, and hanging free from the timbers. Fine copper wire is the best for all this work, and eight or ten pound lead bobs satisfactory.

Then stretch a wire (*b*, *b*), down the inclined part of the shaft, securing it to the timbers, and having the ends moved back and forth until it is fairly tangent to the two plumb wires (*a'*, *a*). If



now another wire (*c*, *c*) be stretched and secured tangent to the one plumb (*a*), and the inclined wire (*b*, *b*), and prolonged into the cross cut, the meridian is secured, and can be made permanent by fixing points in the timbers above *c*, *c*.

Another way to secure the meridian will be to set the transit up

in the cross-cut, approximately in line with *a* and *b*, *b*, measuring the distance *a'* appears to stand on one side or the other of *b*, and calculate from similar triangles how much the transit is to be moved (*B*) testing the position after each such move for accuracy.

Horizontal and vertical distances from the surface station must be obtained by taping and slope-rule readings.

There are some points of detail which should be added to the above general description.

In the first place, it is a matter of some importance on which set of wires the succeeding wire is made tangent. Take, for instance, the case in the sketch; if *b*, *b* is tangent on the hither side of *a'* + *a*, then at the bottom of the shaft the hither side of *a* and the further side of *b*, *b* are in the meridian, and the stretching of *c*, *e* tangent to those sides will not give the true direction (*A*). A very fine wire will, indeed, minimize this, but the most accurate way is shown in *A* by the dotted lines; or better still, to use the transit and sight to the edges of the wires.

In the second place, while the adjustment of the tangent wires can generally be accomplished by fastening to 60 d. wire nails in approximate position, and obtaining final accuracy by bending the nails. It is sometimes advantageous to fasten the wire to a short piece of board, spiked to the timbers through a slot, which will allow considerable lateral adjustment.

In the third place, when plumb-bobs are used in deep, windy, or wet shafts, they can be quickly steadied by immersion in water, with a little thick oil on top to keep it undisturbed.

The case given here is the simplest, but the method can be applied, with a little ingenuity, to any broken-backed shaft with the restriction given above.

Where underground directions are uncertain, as in the case of a shaft where the timbers are twisted, it is often best to work upwards.

ANALYSIS OF CRETACEOUS CLAYS FROM LONG ISLAND.

By C. H. JOÜET.

Clays Dried at 212° F. to Constant Weight.

	White Clay from Northport.	Black Clay from Northport.	White Clay from Sea Cliff.
Silica	68.34	58.84	62.35
Alumina	19.89	23.40	23.14
Ferrous oxide	0.90	1.18	1.12
Lime	0.35	none	none
Magnesia	trace	none	none
Carbonic acid	none	none	none
Sulphuric acid	none	1.03	1.09
Potash	3.55	5.04	3.17
Soda	0.84	0.34	1.76
Combined water	6.03	9.20	6.77
	99.90	99.03	99.40

The first two came from the pits of the Northport Clay and Fire-sand Co., and the third from Carpenter's pit, Sea Cliff. Attempts were made to discover diatoms by panning samples of each of these, but without success.

VITRIFIED BRICK FOR STREET PAVEMENTS.

By T. W. GIBSON.*

The Quality of Road Materials.

To the maker of roads and streets a wide choice of materials is open. In some of the Southern States, for instance, the shells of the oyster are pulverized and spread out in a glistening pavement, and wood of various sorts and in many forms invites use by its cheapness and adaptability. The corduroy of the bush settlements,

* Report of Bureau of Mines, Ontario, 1893.

whose spring-breaking joltiness is preferable only to the mud of the swamps through which it is laid; the plank roads, once common; the cedar blocks of our towns and cities, not to speak of the cubes of real mahogany with which the fastidious rulers of Paris are now said to be ornamenting the streets of that luxurious city at a cost of £2 per square yard—all testify to the utility of wood for paving purposes.

But it is naturally to the mineral constituents of the earth's crust, either in raw or manufactured form, that the road-builder looks when it is determined that art must be called to the aid of nature. The mud road of the country is tolerable, even comfortable, in summer when the dust does not ride on the wings of the wind; but when the spring or fall rains have converted the clay or soil into a glutinous mass of varying depth, or when the pathmaster has just finished laying on his annual contribution of loose gravel or soft earth, travel becomes difficult and hauling of heavy loads impossible. Gravel roads, such as are found in some parts of western Ontario, when well-made and kept in repair, afford an agreeable contrast to the ordinary mud roads, and really add largely to the value of the farms in front of which they pass. Broken stone is a step in advance of round gravel, but in this country Macadam numbers few followers outside of towns and cities; and in the latter, macadamized surfaces, though suitable for light traffic, are falling into disfavor because of their uncleanliness and the expense entailed by constant repairs.

For city streets, stone or granite sets, asphalt and vitrified brick are all in use, and each one of these several materials possesses excellent qualities for paving purposes. As compared with wooden blocks, each of them is preferable in almost every particular, except in the important one of cost.

CEDAR BLOCK PAVEMENTS.—The vast stretches of cedar block pavement which have been laid down in the city of Toronto, for instance, cannot fairly be said to have been successful. On side or residential streets, where the butcher, the baker, the grocer and the milkman provide the bulk of travel, cedar blocks do tolerably well. They are not expensive to lay, repairs are easily made, and where the traffic is light they preserve an even surface for a considerable length of time. But where heavy loads are numerous and travel constant, cedar blocks are altogether out of place. The edges soon wear off, leaving each separate block of a rounded,

almost semi-globular form, and producing a surface comparable in roughness to that of a swamp corduroy. The porous nature of the blocks permits them to absorb a very large portion of the liquid filth which falls on the street, and this, added to the dirt, droppings, etc., which lodge in the hollows between the worn blocks and which ordinary street cleaning is powerless to remove, forms a mass of decaying, germ-breeding matter not only offensive to the sight and smell, but injurious to the public health. The life of a cedar block pavement varies somewhat in proportion to the travel over it, but on heavy traffic streets in cities it does not exceed four or five years. Where traffic is light, another source of decay is in the blocks not being kept constantly moist, but being alternately wet and dry they succumb to rot almost as soon as they would have done to the wear and tear of heavy traffic.

GRANITE PAVEMENTS.—The good qualities of a granite pavement are many. It is not indestructible, but it is adamant compared with wooden blocks; and in a list of all the materials used for street paving, so far as time and experience have yet disclosed their relative durability, the first place would probably belong of right to granite. Possessing this prime requisite for paving purposes—high powers of resisting wear—and being comparatively unobjectionable from a sanitary point of view, were granite smooth and inexpensive, one would probably be tempted to look no further for a paving material. . . . . There are vast stores of granite in the archæan formations of our own Province, much of it convenient for shipment by water or rail; and in places where dray and freight traffic impose their severe tax upon the resisting qualities of pavement, a granite will probably always remain in use, notwithstanding its comparatively high cost. The expensiveness of granite is due largely to the amount of labor necessary to properly dress and shape it, an item which cannot be avoided and which is not offset even by our comparative nearness to the places of supply. A granite pavement affords a better foothold for horses, especially in wet or frosty weather, than asphalt, but it is not so smooth, and its adverse effects upon both horses and vehicles is certainly very much greater.

ASPHALT PAVEMENTS.—Asphalt pavement is exquisitely smooth. It offers less resistance to the passage of vehicles than any other pavement known, and is very easily swept and kept clean. From a sanitary point of view it is entirely unobjectionable, and when

made of pure lake asphalt it is durable. Carriages and wagons make little or no noise passing over it, but the clatter of the horses' hoofs is not inconsiderable. The drawbacks to asphalt pavement are its very high cost, its slipperiness, especially when covered with a coating of ice or sleet, and the injury and expense attendant upon disturbing it for repairs to sewers, gas-pipes, etc. . . . . There is also a difficulty in making repairs to asphalt pavement, as it is no easy task to fuse the new material with the old, and if this is imperfectly done a weak spot is left to become a centre of disintegration. The life of an asphalt pavement is variously stated, some placing it at from seven to ten years where the traffic is heavy, and from sixteen to twenty years where it is light. There has not as yet been sufficient experience with asphalt in our own climate to judge with accuracy how long it may be expected to last under ordinary conditions, but the figures given above are probably not far from the mark. Very much, however, depends upon the quality of the material and work.

BRICK PAVEMENTS.—A brick pavement made of good material, properly laid, is almost everything that a pavement should be. It is smooth, ranking in this respect next to asphalt, and consequently offers a minimum amount of resistance to the passage of traffic, and inflicts a minimum of wear and tear upon horses and vehicles. It has the advantage over asphalt that, while it is smooth, the small spaces between the bricks afford a foothold for horses and prevent their slipping. So far as sanitation is concerned, it leaves little to be desired. It can be swept, cleaned and washed with ease, ranking in this respect next to asphalt, and far superior to granite or wood. It has none of the absorptive properties of wood, being nearly as impervious as asphalt and granite, and consequently escapes the odium which attaches to wood pavements of harboring filth and deca ing organic matter. No pavement is noiseless, but in this particular brick comes next to asphalt and excels granite, being quite devoid of the "bumpiness" which characterizes the latter. It is easily laid and easily taken up when underground repairs are to be made, being almost as convenient to handle as wooden blocks and quite as much so as granite. The question of the durability of brick pavements is one that has been much discussed, but although American experience in this line has been largely confined to the last ten or twelve years and a final judgment cannot therefore be pronounced, it is everywhere the

opinion that, in point of durability, brick is not excelled by any other material. The first streets paved with brick in America are at Charleston, W. Va., and Bloomington, Ill., where the pavement has been down about twenty years. In the former place it has given "entire satisfaction," and in the latter the verdict is equally favorable. It "gives universal satisfaction and stands heavy traffic, showing no signs of wear." At Wheeling, W. Va., where there are twenty miles of brick pavement, the first was laid in 1883. There, too, the city authorities are emphatic in its praise as being economical, durable, sanitary and smooth.

Paving Brick in Modern Towns and Cities.

The use of brick for paving purposes is of comparatively modern origin. Streets in some towns of continental Europe and England have been laid with brick for many years, but it is in the United States and within the last ten years that the reign of paving brick may be said to have begun. To show the extent of the favor to which it has already attained, it has only to be said that in September, 1893, there were in the United States no less than 139 manufacturing establishments in which street brick were made, and 311 towns and cities in which brick pavements were in use. Some of these manufactories are of great size, turning out as many as 60,000,000 of brick per year, and the industry is still rapidly expanding. Nor is the use of paving brick confined wholly to the smaller class of towns or cities. Among the large places which are giving it a trial are Boston, Detroit, Washington, Minneapolis, St. Paul, Buffalo, Rochester, Cincinnati, Cleveland, Kansas City, Atlanta, Louisville, Pittsburgh, Philadelphia, and Chicago. A recent list shows that in the State of Michigan 8 cities have given in their adhesion to brick; in West Virginia, 9; in New York, 16; in Indiana, 17; in Iowa, 20; in Pennsylvania, 39; in Illinois, 44; and in Ohio, 56.

The testimony given by these places is almost unanimous in favor of brick as a paving material. Judge E. H. Thayer, of Clinton, Iowa, President of the Iowa Road Improvement Association, says in a letter to the bureau, dated March 22, 1894: "Vitrified brick for street paving is in general use in the west. For heavy traffic there can be no superior, and it answers the purpose fully as well as granite. In my opinion, it is the paving of the future of this entire country." Charles P. Chase, C.E., author of

the handbook entitled *Brick Pavement*, published in 1891, says, under date of April 6, 1894: "If the best quality of brick is used and the work well done, I have no doubt but that it is the cheapest and most durable pavement for the money that can now be obtained. The best brick well laid will make a pavement as good as granite, except on streets where the heaviest traffic is carried on. It is easily laid or removed for repairs, is clean and sweet as compared with wood, and not as slippery as asphaltum or granite, and not as noisy as granite." In a letter dated March 27, 1894, Mr. A. W. Cooke, Chief Engineer Department of Public Works, Chicago, says: "As compared with asphalt, granite, and cedar block pavement, vitrified brick ranks second as to first cost; first as to cost of maintenance; first as to ease with which it can be repaired; first as to durability under traffic; third as to noiselessness; second as to freedom from dust; first as to freedom from decay; second as to freedom from absorption; first with granite as to foothold for horses; and second as to ease of traction. In a sanitary point of view it is without a superior, and, excepting asphalt, without an equal." The city engineer of Memphis, Tennessee, states that the pavements of that city are principally granite, limestone, gravel, macadam, and vitrified brick. Of the last he says: "It has been in use in the city of Memphis under medium heavy traffic since April, 1889, during which time the city has not spent one dollar for repairs except where the pavement was torn up for repairs of gas- and water-pipes. It has given general satisfaction in Memphis as a sanitary pavement, being easily and economically cleaned. It is comparatively free from noise, and does not tax the nervous system like the stone and granite pavements. The surface is smooth, pleasing to the eye, and affords a fair foothold for horses."* Many other similar expressions of opinion could be quoted. The sincerest testimony, however, which can be given is the rapidity with which the cities in all parts of the United States are adopting the new pavement. There are 60 miles of it in Philadelphia and Germantown; 85 miles in Columbus, Ohio; 10 miles in Indianapolis; and 5 in Cincinnati; while New York, which has experimented with every variety of street material, is now paving Broadway south from Central Park with brick. The city engineer of Washington says: "Owing to their more enduring qualities, we

* *Paving and Municipal Engineering*, February, 1894, p. 55.

are paving all alleys with vitrified brick and repaving the gutters of streets paved with asphalt with them, as they have better wearing qualities, and are not affected by water or uric acid from horses, as is asphalt, and most of the new pavement is being laid with brick." The cities of the very first class, such as New York and Chicago, have been somewhat slow in making use of the new material, doubtless because of a suspicion that it might not withstand the impact of heavy loads and constant travel. Yet in the latter city the Chicago, Burlington and Quincy Railway Company experimented with stone, asphalt, and cedar blocks at its freight yards, and, after discarding all for various reasons, put down brick, with the result that after a tonage of 12,500 tons had passed over it daily for four years, not a broken brick could be found. That company is so well satisfied with its experience in Chicago that it now uses it for paving all its yards where there is heavy traffic, its recent order for the St. Louis yards being a million and a half of brick.

In the May (1894) number of *Paving and Municipal Engineering*, a forecast is made of the extent and cost of public improvements to be made this year in fifty-four cities of the United States, based on returns received by the editor. Thirty-two cities report projected pavements as follows: Asphalt, 288,163 square yards; brick, 524,143 square yards; and macadam, 383,086 square yards. The figures representing the cost are incomplete, but it is significant that the area proposed to be laid with brick is much larger than that to be covered with either asphalt or macadam, and is nearly equal to that of both combined. Louisville, Kentucky, appears in the list for 150,000 square yards of brick at a cost of $525,000, but the bulk of the outlay for brick streets is undertaken by cities of moderate size. Thus Burlington, Iowa, is down for 40,000 square yards, costing $75,000; Decatur, Ill., for 33,000 square yards, costing $50,000; Danville, Ill., 40,000 square yards, costing $75,000; Huntington, W. Va., 20,000 square yards, costing $25,000; and Tiffin, O., 25,000 square yards, costing $68,000. On the other hand, Chicago proposes to lay 39,000 square yards of asphalt at a cost of $117,000, and 250,000 square yards of macadam at a cost of $225,000, while it is investing in only 6000 square yards of brick, costing $12,000. Milwaukee is covering 100,000 square yards, and Indianapolis 95,066 square yards, with asphalt, while the latter city proposes besides to lay 40,700 square

yards of brick. It is evident, therefore, that while some cities of the first class are slow to commit themselves to brick pavements, brick is fast becoming, if it has not already become, the favorite material for towns and cities of less than the largest size.

In Toronto, Ontario, there are four miles of streets paved with vitrified brick, all of which were laid down last year. The pavement is between the street-car rails only. The bricks of which it is composed are all imported from the United States, partly from Masillon, Ohio, and partly from Canton, Ohio. The foundation is a bed of concrete, on which is laid a cushion of sand one inch in thickness, and on this the bricks are placed on edge at right angles to the kerb. They are laid as close to one another as possible, and the interstices are completely filled with paving pitch or Portland cement. The cost of paving brick laid down in Toronto is from $20 to $23 per thousand, made up as follows: Price at place of manufacture per thousand, $9 to $10.50, freight $9 and duty $3. It takes from 60 to 64 bricks to lay a square yard of pavement, allowing for breakages. The brick pavements in Toronto having been down scarcely a year do not afford data for a conclusion as to their durability; we expect them to be yet practically uninjured and as good as when laid down. This on examination we find to be the case, and although, owing to the pavement being between the car rails only and thus by its position as well as by its smoothness offering a double inducement to vehicles of all kinds, it has received more than its fair share of travel, the only visible mark of wear is a slight rounding off of the edges of the bricks. The comparative cost of the various kinds of pavement used in Toronto is as follows, including foundations:

	Per square yard.
Cedar block on 6-inch sand,	$ 75
Cedar block, on 2 layers of 1-inch boards, with tar composition,	1 30
Cedar block, on 6-inch concrete,	1 50
Light asphalt, 4-inch concrete, 2-inch asphalt,	2 10
Vitrified brick, on 4-inch concrete,	2 25
Heavy asphalt, 6-inch concrete, 2½-inch asphalt,	2 60
Granite sets on 6-inch concrete,	3 85
Scoria blocks on 6-inch concrete,	4 00

The city authorities are very favorable to the use of brick as a paving material, considering it suitable for traffic of any kind, whether heavy or light. If good paving bricks were made in

Toronto and sold for the same price as that charged by the United States manufacturers in their own markets, a saving of from 65 to 75 cents per square yard over present cost could be effected, which would reduce the cost of brick pavement to practically that of cedar blocks.

The cost of brick pavements in the United States varies considerably with the kind of foundation employed. It ranges from $1 to $2 per square yard, the average being perhaps about $1.50. The cost of the bricks themselves for a single course pavement at a selling price of $10 per thousand is about 65 cents per square yard. A few samples of the cost of brick pavements, together with the various kinds of foundations and methods of laying the brick adopted, may be quoted from Mr. Chase's manual, above referred to.

In Bloomington, Ill., where some of the pavements are twenty years old and but little worn, the manner of laying is as follows: The foundation is brought to proper shape and well rolled; then a course of cinders is spread on and compacted by rolling; on this is placed two inches of sand; then the first course of bricks on their flat sides with their long axes parallel to the street. Next comes an inch of screened sand, and then a layer of bricks edgewise on their 2 inch surface, and long axes at right angles to the street. The bricks are then covered with sand, which is swept into the cracks, and the whole pavement rolled with a heavy roller. There is no necessity of the sub-course of brick being as hard as the upper course, but care must be taken to break joints in both courses. The entire pavement, including all materials, cost $2 per square yard. A line of pavement running to the depot had, in 1891 been down for seven years, carrying all the freight to the railway and all coal from the coal shafts, a very heavy traffic, without showing any appreciable sign of wear.

In Decatur, Ill., the specifications required: (1) foundation brought to desired crown 12 inches below grade and rolled with a heavy roller; (2) a course of clean gravel, none larger than a robin's egg; (3) one couse of brick flatwise, then 1½ inches sand, and a course edgewise, and brick brought to a surface by striking with a maul on a plank; (4) sweep in dry sand; (5) brick extra hard and vitrified. The cost is $1.50 per square yard. The oldest brick pavement at this place had been down six years in 1891, and then showed but little wear.

At Steubenville, Ohio, hard burned bricks are used, chiefly obtained from New Cumberland, West Va., and have given satisfactory results. They are laid on foundations of gravel similar to that used at Decatur. The wear is estimated at ¼ to ½ an inch in five years. Cost of pavement, $1 per square yard.

At Peoria, Ill., Franklin Street, which in 1891 had been paved with brick three years and a half, is one of the principal thoroughfares and has a very heavy traffic. It was as pleasant to ride on as asphalt, and showed little or no signs of wear. The bricks used were larger than ordinary, being 4 inches thick, 12 inches long and 5 inches deep. They were laid on 5 inches of rolled gravel, the joints being filled with sand. Contract price, $1.70 per square yard.

In an article on the Manufacture and Use of Paving Brick, read before the International Engineering Congress of the World's Columbian Exposition by Daniel W. Mead, that gentleman gives a table of 42 cities in the United States where brick pavements are in use, showing the number of years the pavement has been down, the kind of foundation, the average cost per square yard and other particulars. Cincinnati is shown to have laid a quantity of pavement four years ago on 6 inches of concrete at a cost of $2.50 per square yard; a similar pavement in Indianapolis cost $2.40 per square yard; one in Wheeling, West Va., laid eleven years ago on 8 inches of gravel, cost $1.35 per square yard, while the premier pavement in Charleston, West Va., placed in position twenty-three years ago on a foundation of 3½ inches of sand and tarred boards, cost only $1.15 per square yard. In the cities of Illinois and Iowa, where paving brick is more largely used than in any other part of the United States, except perhaps Ohio, a variety of foundations is employed, comprising broken stone, cinders, sand, gravel, concrete, and usually a course of brick laid flatwise, which may be of inferior quality to those forming the actual surface of the street. A common foundation is 6 inches of broken stone, covered with 2 inches of sand, either with or without the overlying sub-course of brick laid flat. Six inches of concrete is also frequently used, and sometimes sand alone forms the bed on which the bricks are placed.

In the last-mentioned case the expense is low, as at Council Bluffs, where the pavement is stated to have cost only $1.32 per square yard. A pavement resting on 6 inches of broken stone

with a course of brick flat cost at Alton, Ill., $2.16 per square yard; at Springfield, Ill., one on 6 inches of cinders cost $1.50 per square yard; at Clinton, Iowa, one on 6 inches of broken stone with sand, $1.35 per square yard; and at Dubuque, Iowa, 6 inches of concrete foundation brought the total cost of pavement up to $1.69 per square yard.

Foundation for a Brick Road-Bed.

A good foundation is as essential with vitrified brick as with any other kind of paving material. However excellent the surface covering of the street may be, it cannot but fail of achieving the best results if it does not rest on a proper substructure. The road-bed should be thoroughly drained, so as to secure the greatest possible freedom from moisture, that arch enemy of pavements, equally objectionable in fluid or frozen form. When brought to proper sub-grade, the whole surface of the roadway should be thoroughly consolidated by rolling or ramming. If the bed to overlie this is of gravel or broken stone, it should consist of pieces of uniform size, not too large, and free from dirt. If of concrete, the sand entering into the latter should be sharp, the cement of first-class quality, and there should be a due proportion of each in the mixture, say, three parts of sand to one of cement; and the fragments of stone to complete the concrete should be angular with rough faces, clean, and not excessive in size. The concrete, when deposited on the sub-grade, should be rammed until loose mortar appears on the surface, and sufficient time should be allowed for it to set before placing the brick in position. On the concrete a layer of sharp, dry sand should be spread to the thickness of an inch, or an inch and a half, to act as a cushion on which the bricks may rest. The bricks are placed on this, on edge, at right angles to the street, and, in order that the joints may be broken, each alternate row should start at the kerb with half a brick. The bricks should be as close to one another as it is possible to lay them, and the interstices filled in with sand, paving pitch, or cement. The last named is preferable for a lasting and substantial piece of work, as it is impervious to water, and not loosened by the heat of the sun, which is not the case with sand and paving pitch, respectively. A drawback to the use of cement for this purpose, is the length of time it takes to harden, while the pitch consolidates in a few minutes. It is difficult to exclude traffic

from a street long enough to allow the cement to thoroughly and properly set.

It is frequently necessary to disturb the surface of the street in order to make repairs to sewer and gas pipes, water mains, etc., and the facility with which a pavement can be taken up and relaid is an important consideration. Brick is far ahead of asphalt in this particular, and is as easily taken up and relaid as either granite or wooden blocks. When the joints between the bricks are filled with sand, the bricks may be removed, cleaned, and placed in position again with little or no trouble; but, if pitch or cement be used, such repairs generally involve the destruction or rendering worthless of the bricks removed.

It is evident that, for heavy and constant traffic, a foundation such as is described above, is an absolute necessity, if a brick pavement is to have a fair opportunity of proving its smoothness and durability. For lighter traffic, a less expensive foundation may suffice. The engineer of an Ohio town states, that last year he put down a considerable area of brick pavement on a foundation of six inches of clean gravel and one inch of sand. The usual drain-pipes were omitted. The whole pavement, when completed, cost $1.28 per square yard. Such construction might, perhaps, serve the purpose in small towns, but could scarcely be expected to stand the strain of heavy traffic. Mr. Mead says:

"For light traffic, the fragmentary materials (rubble, gravel, sand, etc.), or sand with a layer of brick laid on their side, or six inches of concrete, make good foundations, the selection depending on the local resources. For medium traffic, nine inches of stone or gravel, or six inches of gravel or stone with a layer of brick laid on their sides, bedded in sand, or six inches of concrete, will give good results. For heavy traffic, the stone or gravel should be at least one foot in thickness, or the concrete at least nine inches."

Bricks of the standard size are to be preferred. They are more likely to be thoroughly vitrified than larger blocks, which are frequently found unvitrified in the centre, and they possess an additional advantage from the manufacturer's point of view. In almost every kiln of brick burnt there is a percentage of the output too soft for paving purposes. These, if of the ordinary size, may be used in building, or for sewer arches, while if too large or of an odd size they would be hardly salable.

Best Clays for Paving Brick.

All clay will not make good paving brick. Clay that will yield excellent building brick may be altogether lacking in the qualities necessary for good paving material. A brick that is made from coarse clay, or one that has an excessive percentage of sand, will be open and porous or easily broken, and unfit for paving purposes. The best bricks are those made from a tough, plastic, smooth clay, with a fine grain, that will burn hard without warping, twisting, or melting easily under a strong heat. It is impossible to determine, either from the physical properties or the chemical analysis of a clay, whether it will produce a satisfactory paving brick. The latter method of examination may indeed suffice to give a negative result; that is, if it reveals a large preponderance of undesirable, or an insufficient proportion of necessary elements, we may conclude that the clay in question is unsuitable for the purpose. But a sample of clay which passes muster under chemical analysis, may fail when subjected to actual test. "The analysis of a clay is only presumptive evidence of its adaptation to the various departments of clay-working, and never to be taken as conclusive. The intense heat of the kiln may effect decomposition and develop combinations which are beyond the reach of chemical reagents. The presence of a great mass of highly-heated material sometimes exerts an influence that cannot be produced in the laboratory."*

Mr. Edward Orton, Jr., E.M., in a series of papers on the "Clay-Working Industries of Ohio," which have appeared in *The Clay Worker*, agrees that the only conclusive test of the quality of a clay is actual trial. He says: "The heat-test of clays, whether applied in special furnaces or kilns in a laboratory, or carried on in the ordinary course of manufacture in the kilns of a clay plant, is the only important and convincing test which we can apply. Even the predictions of a chemical analysis are secondarily useful, for, while they are founded on the results of well-known laws, there are still too many unknown and unexplained contingencies in the composition of clays to make a chemical prediction more than a reasonable probability. By an analysis, certain things are indicated; we expect a fire-trial will develop a result in accordance;

* Professor R. T. Brown, formerly chemist of the United States Department of Agriculture, in *Brickmakers' Manual*, p. 167.

it probably will, wholly or in part; but it is usually only in part, for such is the infinite variety of composition and combination in clays, that their products are somewhat like the human face, no two alike."*

Clay is the immediate or ultimate product of the decomposition of feldspar, chiefly of the feldspathic ingredients of granitic rocks. The essential constituent is a hydrous silicate of alumina, known as kaolin, composed of silica 46.3 per cent., alumina 39.8 per cent., and water 13.9 per cent. This may be considered pure clay, which is rarely met with in nature. The clays of common occurrence contain a larger proportion of silica and a smaller proportion of alumina than kaolin, and variable quantities of numerous other ingredients, the chief of which are lime, magnesia, potash, soda, and iron. The alkaline constituents of clay may be either the elements contained in the feldspar of the original rock, or, derived from extraneous sources; the iron is probably in most cases an added element, though originally present in some feldspars as a coloring matter. Clays, considered with reference to the manner of their occurrence, may be either residual or sedimentary. Residual clays are the product of the disintegration of rocks in place, and where such a process has gone on, free from the intrusion of other impurities, the leaching out of the alkalies may have left a bed of pure or nearly pure kaolin. Sedimentary clays are those which have resulted from the grinding up of rocks by glacial action, or the working over and transportation of residual beds. This class of clays is more likely to have retained the original

* *The Clay-Worker*, April, 1894, pp. 147–8. Mr. Orton's work in the line of clay-working and ceramics has recently been recognized. By enactment of the General Assembly of Ohio, a course of Practical and Scientific Instruction in the Art of Clay-working and Ceramics was added to the educational work of the University of that State. The department has already been organized, with Mr. Orton as director, and the first term opens on September 12, 1894. The course is intended to afford to young men engaged in brick-works and potteries an opportunity to gain as much knowledge of the principal scientific studies touching their craft, with as little expenditure of time on other branches of science not so closely related to their work, as is possible. The course extends over two years, and the instruction covers physics, physical geography, chemistry, algebra, geometry, shop-work, clay-working, general and economic geology, mechanical drawing, and drill. Particular attention will be given to chemistry, including the analysis of clays, limes, cements, feldspars, pottery, glass, glazes, slips, enamels, etc. Tuition is practically free. This is the first instance in the history of this continent in which steps have been taken to put the ceramic industries on the plane occupied by those of mining, metallurgy, and agriculture.

composition of the rocks from which they were derived. Clays are found in all geological formations, except the very oldest, and in many cases have, through the influence of heat and pressure, become indurated into compact rocks or shales. No one geological series has a monopoly of clay suitable for the manufacture of paving brick. The shales of various ages are now extensively used for the purpose, and even some drift clays, subjected though they have been to so many vicissitudes, and exposed to contamination from so many sources, have been found to possess the requisite qualities.

An examination of the analyses of samples of clay used in making paving bricks in various and widely separated portions of the United States, shows that a considerable range is permissible in the proportions in which the main ingredients are present. It does not appear to be essential that the silica and alumina should bear any fixed relation to each other in quality. In some samples the former is high and the latter low, while in others the reverse is the case, with apparently little or no effect upon the quality of the product. Alumina shrinks, warps, cracks greatly in drying, but gives plasticity and adhesiveness to the clay and strength to the product. Silica prevents cracking and distorting, the more silica being present the less the shrinkage. But, the greater the proportion of silica the less the plasticity and adhesiveness of the clay, and the weaker and more brittle the product. Neither does there appear to be any fixed standard for the fluxing constituents, either singly or taken together. What is doubtless true is, that these should not fall below a minimum, otherwise the clay would refuse to vitrify; nor exceed a maximum, otherwise it would fuse too soon, and melt out of shape at too low a heat.

On the subject of the physical and chemical qualities of vitrifying clay, Mr. Orton writes as follows in the series of articles above referred to:

"In examining the subject, it is found that clays used for making vitrified brick are chemically different from those used in making any other form of vitrified wares. Hence, the following statements may be applied to all clays in which vitrification is an essential quality:

"The term vitrified is defined as indicating the incipient fusion and fritting of the particles of the clay ware into a new chemical compound, not necessarily glassy, but indicating by its fracture that such a chemical union has begun to take place.

"The degree to which such vitrification has taken place in a burnt clay is measured by its ability to absorb water, for as the chemical union progresses the pores of the clay become more and more constricted and the appetite for water less and less. If the clay be a good vitrifying variety, it will absolutely cease to absorb water at a temperature some distance beneath its melting-point. Other clays, burnt at something near the same temperature, may enter into combination to a certain extent, but still absorb water freely. Such clays are, perhaps, somewhat vitrified after being burnt under such conditions, but under the classification proposed they must not be included as vitrifying clays.

"The physical peculiarities which mark vitrification in a burnt clay are the conchoidal fracture, absence of pores and blending of the ingredients into one mass. Cracks, fissures and cavities may be found, but porosity must not exist in a well-vitrified clay, and the original particles must have begun to cohere by the bond of heat instead of the bond of plasticity.

"It is impossible to convey adequately by words the peculiarities of fracture which indicate vitrification, but it is a quality which the natural sense of any observer readily teaches him to detect.

"Vitrification is thus seen to be a physical state or condition which any clay may assume if it is heated to the requisite point. The qualities which a clay must have to be profitably made into vitrified product are as follows:

"1. There must be a balance between the vitrifying temperature and the fusing temperature. Some clays begin to vitrify at low heat, and become perfectly non-absorbent without ever approaching to a point where the clay becomes soft or bloated. Others stand heat well up to a certain limit and then fail rapidly. Obviously, the latter would not do for a vitrified product, for it would be impossible to burn a kiln of it without overburning a large quantity in order to obtain a sufficient heat to cause the rest of the kiln to properly vitrify. There must be a margin, or a tolerably broad range of temperatures, inside of which the vitrifying action takes place without approaching fusion.

"If a clay have this first great condition, it can be profitably worked, but its value will depend partly on two other factors—2d, plasticity; 3d, color.

"2. The importance of the requisite plasticity is easily seen; for if it is not possessed, it must be obtained by mixture, which may interfere with the first and more important quality of vitrification.

Again a balance of qualities is needed. Too great plasticity causes imperfect arrangement of the particles of the clay in passing through the die of the machinery. Too little causes surface imperfection, cracks, toughness, etc. The majority of the vitrifying clays are not naturally very plastic as they occur; they may have been once, but the quality is gone, and it is only by fine crushing and very thorough tempering that plasticity sufficient can be induced. However, the faults of plasticity can largely be conquered by the use of proper mechanical means, while the vitrification depends on inherent chemical properties which we cannot vary or alter.

"The color of the ware is only important in view of a singular prejudice which the public have cultivated against light-colored materials. The popular idea is that vitrification is measured by the dark color of the product, and that light colors are *prima facie* evidence of softness. This is by no means true. Many of the impure fire clay beds of the State make most excellent vitrified brick, but cannot be sold on account of their naturally light color. This difference is due more to the condition of the iron present than to its amount. In the light-colored clays the iron is largely present as grains, while in most shales it is in the state which affects equally every particle of the clay, whether chemically combined or not."*

Mr. Orton goes on to enumerate the sources from which vitrifying clay is obtained in Ohio. He states these as three: (1) The shale-clays, coming largely from the coal-measures, but represented in all of the older deposits as well; (2) The impure and low-grade fire-clays, coming from the coal-measures; (3) River-clays or sedimentary deposits of recent origin.

It is stated by Mr. Orton that none of the three classes of clay enumerated above is in itself a perfect material for the purpose to which it is applied, though instances are found in which each is used alone with satisfactory results. The shales and river-clays are too fusible and lose their shape at too low a heat, but vitrify perfectly. The fire-clays are more refractory, owing to their high percentage of silica and comparative freedom from fluxing impurities, and they keep their shape well, but at the expense of vitrification. On this account a mixture of fire-clay with either shale

* *The Clay Worker*, May, 1894, pp. 544, 545.

or river-clay improves the quality of the product. As regards plasticity, the shales are, as a class, not sufficiently plastic to work alone; the river-clays are too plastic, while the fire-clays leave little to be desired in this respect. As to color, the shales and river-clays burn dark, the fire-clays light. Both in point of plasticity and color, therefore, an admixture of fire-clay with shale or river-clay is found to be mutually advantageous. Mr. Orton gives an analysis of shale-clays used in the manufacture of paving-brick and sewer-pipe at a number of establishments in Ohio, which is as follows:

Elements.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Silica (total)	57.15	58.30	57.10	49.30	57.45	55.60	58.20	58.38	57.28	57.40	56.61
Alumina	20.26	19.67	21.29	24.00	21.06	24.34	22.47	20.89	21.13	21.20	21.63
Water (combined)	5.50	5.15	6.00	9.40	5.90	6.75	6.15	7.53	5.22	7.75	...
Clay and sandy impurities (total)	82.91	83.12	84.39	82.70	84.41	86.69	86.82	86.80	83.86	86.35	...
Oxide of Iron	7.54	7.43	7.31	8.40	7.54	6.11	5.63	5.78	8.52	6.57	7.08
Lime	.90	.84	.29	.56	.29	.43	.62	.44	5.79	1.00	1.11
Magnesia	1.62	1.35	1.53	1.60	1.22	.77	.98	1.57	2.13	1.40	1.41
Potash	3.05	3.04	3.44	3.91	3.27	3.00	3.08	4.68	.....	4.10	3.51
Soda	.58	.73	.61	.19	.39	.09	.42	.34	.....	1.00	.48
Fluxing impurities (total)	13.69	13.39	13.18	14.63	12.71	10.40	10.73	12.81	16.44	14.07	...
Moisture	2.70	2.65	1.30	1.20	1.90	2.65	1.65	...	...	...	...
Total	99.30	99.16	98.87	98.54	99.02	99.74	99.20	99.61	100.07	100.42	...

1. Bucyrus Brick and Terra Cotta Co., Gloucester, shale.
2. Bucyrus Brick and Terra Cotta Co., shale and plastic clay mixed.
3. Royal Brick Co., Canton, O., Canton shale.
4. Waynesburg Brick and Clay Manufacturing Co., Waynesburg, shales.
5. Ohio Paving Co., Columbus, O., Darlington shales.
6. A. O. Jones Co., Zanesville, O., shale and fire-clay mixture.
7. T. B. Townsend & Co., Zanesville, O., shale and fire-clay mixture.
8. Columbus Sewer Pipe Co., Columbus, O., Huron shales.
9. Akron Vitrified Press Brick Co., Independence, Bedford shales.
10. Akron Vitrified Press Brick Co., Independence, another sample.
11. Average of preceding ten analyses.

The average composition shows a clay containing 84.78 per

cent. of clay base and silicious matter and 13.22 per cent. of fluxes.

In *The Mineral Industry* (1893) a table of analyses is given of paving-brick clays from a number of localities in the United States, which is said to be very complete and compiled from official sources. The table is interesting for purposes of comparison with the one just quoted. It will be noted that the average silica contents of the clays cited therein is considerably higher than that of the shales whose analyses are given by Mr. Orton.

Locality.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	TiO_2.	Alk.	H_2O.
Bloomington, Ill.	67.80	11.55	6.50	8.90	5.32	.....	2.42	0.20
Burlington, Ia.	77.40	11.74	12.31	1.60	1.91	.....	4.23	.....
Clinton, Ia.	73.82	15.88	9.16	trace	trace	.....	4.50	3.50
Franklin Co., Kan.	59.60	17.86	14.94	0.79	0.81	.....	.....	6.00
Leavenworth, Kan.	58.45	21.96	8.43	1.05	1.47	.....	4.00	6.51
Flint Ridge, Kan.	58.20	29.80	5.40	6.00	.....	.....	.....	0.60
Cheltenham, Mo.	61.22	25.64	3.47	.....	.....	.....	1.31	9.68
Montgomery, Mo.	43.93	40.09	1.70	.....	.....	.....	0.20	14.60
Kansas City, Mo.	64.37	19.73	9.07	0.82	2.32	.....	3.78	...
Cumberland, W. Va.	69.02	22.07	4.53	1.70	0.38	.....	2.68	...
Nuzum's Mills, W. Va.	59.25	32.26	1.67	7.16	.....	.....	.....	6.30
Mount Savage, Md.	39.90	30.08	0.88	.....	.....	.....	2.30	13.90
Robbins, Tenn.	70.57	15.19	7.97	0.78	0.32	.....	2.30	...
Hornellsville, N. Y.	67.29	15.85	6.16	0.95	0.19	.....	8.71	...
Warners, N. Y.	52.30	18.85	6.55	3.36	4.49	.....	6.00	8.34
Woodbridge, N. J.	42.23	39.53	0.50	0.01	.. ..	1.40	0.49	16.80
Phillipsburg, N J.	56.78	17.38	0.50	4.14	3.15	.....	3.42	7.60
Columbus, Ohio.	57.45	21.06	7.54	0.29	1.22	.....	3.66	7.80
Canton, Ohio.	53.38	19.36	14.86	1.48	1.06	.....	.....	...
East Palestine, Ohio.	57.80	25.54	2.51	0.25	0.61	.....	2.69	10.60
Haydensville, Ohio.	76.24	16.87	0.16	.....	0.50	.....	1.09	4.90
Woodlawn, Pa.	42.15	31.43	2.32	0.32	2.01	1.00	.....	10.60
New Brighton, Pa.	67.36	22.05	5.61	0.86	0.36	.....	5.40	...
San Francisco, Cal.	56.51	21.33	0.29	.....	3.53	.....	trace	6.30
Golden, Col.	52.41	32.21	0.66	0.20	0.60	.....	0.61	14.05
Winchester, Ill.	23.15	17.08	.....	.....	0.28	1.20	1.10	...

These analyses exhibit surprising variations in the composition of materials used for a common purpose, not only so far as the silica and alumina are concerned, but also, in a smaller degree, as regards the fluxing impurities. They are instructive as disclosing the fact that clays of the most unlike constitution are employed in the manufacture of paving brick.

Effects of Fluxing Ingredients on Vitrification.

As regards the part played by the minor or fluxing ingredients of the clay in the process of vitrification, Mr. Mead says:

"Lime and magnesia, while infusible in themselves or with alumina, fuse in the presence of an excess of silica, as do also several other common ingredients of clay, and form a 'vitrified brick.' It is found that potash has the most active fluxing effect on clay, after which follow soda, lime, magnesia, and iron in the order named. To 'vitrify,' a clay should contain at least 3 per cent. potash, or 3½ per cent. soda, or 5 per cent. of lime or magnesia, or 8 per cent. iron, or a combined proportion of any or all of these fluxes equal to these amounts. An appreciably less amount of these fluxing elements will leave the product more of the nature of a fire-brick, unvitrified and porous, and, as a rule, unfit for paving purposes. A greater proportion than above specified is desirable, and will make the clay more easily vitrified at a less heat, and is to some extent a measure of its economic manufacture, as a lower heat and consequently less fuel will be required in its burning. Too great an amount of these fluxes, amounting perhaps to three times the quantities above mentioned, will render the clay hard to handle on account of great fusibility. According to Richter, lime and magnesia are more active fluxing agents than potash and soda, but his conclusions do not agree with American experience. The presence of lime or magnesia in a paving brick in reasonable quantities is not believed by the writer to be detrimental to the brick if it exists in a finely divided state and is intimately commingled with the other constituents, so that a silicate of lime or magnesia will be formed in the burning. The Milwaukee building brick is one of the best of common brick, and it contains a large percentage of lime, and Portland cement contains often as high as 60 per cent. of lime. In each case, however, the lime exists in close chemical union with the other elements of the material. Iron in considerable quantities has a fluxing effect with silica, and to this extent cements it together and gives it strength. It is not the most valuable of constituents in this regard, however, and its presence is not essential to a first class paving brick. Iron, when present, is usually in the form of hydrous peroxide or protoxide of a yellowish or bluish color. During the burning, the water of crystallization is expelled, and the iron takes the form of the red peroxide, giving its color to the material in proportion to the amount present. Potash and soda fuse at a lower temperature than the other constituents of clay, and their presence in suitable quantities is desirable for the manufacture of vitrified paving brick."

Mr. Chase remarks on the same subject:

"Lime is very injurious to the paving brick, as it is changed to caustic lime in burning, and a small amount of moisture reaching this will cause it to slack and disintegrate the brick. A small amount of magnesia aids in producing vitrification. Iron is not injurious in a paving brick; but in a brick to resist high temperature 6 per cent. of iron makes it useless. Alumina, and not iron, gives elasticity to the brick, is tough and binding, readily fusing in the presence of silica. The other constituents are impurities, and act as a flux." *

Physical Properties of Clay.

The physical properties of clay have an important bearing upon its fitness for use in the manufacture of paving brick. The hard, compact shales of the older formations, subjected as they have been in past ages to great heat and pressure, have to some extent lost that plasticity which is necessary to the proper handling and working of the raw material; hence, such shales have to be reduced by mechanical means to a finely divided condition, and carefully tempered by the addition of water before they are in a condition to undergo the processes of manufacture. The fineness of the particles of which clay is composed likewise has considerable influence upon its behavior in the kiln. Coarse clays are difficult to vitrify, even when the fluxing constituents are present in sufficient proportion, on account of their ability to withstand a large degree of heat. The more finely divided the clay, the more readily is it vitrified, and the tougher, stronger, and more impervious to moisture is the product. The several ingredients of the clay may also vary in their action according to the condition in which they exist. On this point, Mr. Mead says: "The uncombined silica may be more or less finely divided, and its condition has its effect on the action of the fluxes. In clays derived from feldspathic or micaceous rocks, undecomposed feldspars and micas sometimes occur. Lime, instead of being finely divided, may occur as lumps or pebbles, in which condition it will unite with the other ingredients only on the surface, the balance burning into caustic lime, which, on exposure, will gather moisture and slack, disintegrating and crumbling the brick." It is even conceivable

* *Brick Pavement*, pp. 14–15.

that two samples of clay, substantially identical in chemical composition so far as the proportions of the several constituents are concerned, may act quite differently in the kiln, owing to the different condition in which these constituents are present in the respective samples. A clay full of fragments of the original rock, for example, would be likely to require a considerably higher temperature for its vitrification than a clay resulting from the more complete degradation of the same rock; and this difference in temperature might bring about the production of two very unlike samples of brick.

One physical property, it may be remarked, is possessed by clays alone among the mineral substances found in nature, viz., plasticity. The cause of the plasticity of clays, by virtue of which they may be moulded into almost any desired form, does not seem to have yet been thoroughly explained, but it evidently depends largely upon the presence of the chemically combined water, as when this is driven off by heat the clay loses its plasticity, which can never be restored. Dr. Koenig, of the University of Pennsylvania, who has made a study of this subject by means of microscopic investigations, states that kaolin or pure clay is composed of minute particles, loosely aggregated and invisible to the naked eye. Magnified 1100 diameters, these infinitesimal particles look like globules, and are not very unlike fish roe in appearance. In Dr. Koenig's opinion these particles are not crystalline, and he lays stress upon their similarity to globules of starch, as they are capable of absorbing water and of enlarging and passing into a plastic paste, the extreme mobility of which is accounted for by his assumption of the rounded form of the ultimate particles. Pure alumina is not plastic; neither is pure silica; yet when in chemical combination as a silicate of alumina there is developed this highly interesting property. If there be more silica present than can be taken up in chemical union by the alumina, the result is a lessening of plasticity, which goes on decreasing in proportion to the quantity of sand added. Clay loses its plasticity entirely at a low red heat, probably about 1000° F.*

* In the appendix to *Brick and Tile Making* (London, England, 1868), Mr. Charles Tomlinson, F.R.S., speculates thus as to the cause of plasticity in clays: "We have seen that clay ceases to be plastic when its chemically combined water has been driven off. Still, however, water cannot be said to be the cause of plasticity as a general property, since we have in melted glass a more perfect example of plasticity

Manufacture of Paving Brick.

The ordinary methods of making common brick require some modification in the manufacture of paving brick. If the raw material is shale, it is first reduced to a powder in a granulator or dry pan, and then thoroughly tempered in a pug mill before passing to the brick machine. The auger type of brick machine is the one more commonly employed, and the clay is handled in the condition known as "stiff mud." The "soft mud" process is not considered applicable to the manufacture of paving brick. Attempts are being made to adapt the "dry press" method, and on certain kinds of clay with a considerable degree of success. The drying of the brick previous to their burning is an important part of the process, and is best done on hot or slatted floors, or in flues or tunnels, by means of artificial heat. Outdoor drying cannot be depended on where the industry is conducted on a large scale. In the actual burning of the brick the best results are obtained by means of the "down-draft" kiln. The fires are started slowly in order to allow the water mechanically held in the clay to pass off as steam, which it does completely at a temperature of 212° F. This process is technically called "water-smoking." When the smoke issuing from the kiln shows no further signs of escaping steam, the heat is gradually increased, and at a little above 1000° F., or a low red heat hardly perceptible in daylight, the combined water also passes off. Any organic matter present is now eliminated and sulphur compounds broken up, part of the sulphur going

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even than in clay, and few substances are more plastic than sealing-wax at a certain temperature. A clear idea of plasticity and of some of the other mechanical properties of matter may probably be gained by considering them as variations of the forces of cohesion and adhesion, and by bringing these in their turn under Newton's great law of attraction, which, whether exerted between atoms or masses, is directly as the mass and inversely as the squares of the distance. . . . . Now the method of arranging the particles of clay at that precise distance that shall impart plasticity is one of Nature's secrets that we have not yet succeeded in penetrating. It may be that the circumstances under which the clay is formed and deposited, or the time that has elapsed since its formation, or the pressure of the superposed layers, may have so arranged the particles as to enable them to become plastic when the proper proportion of water is added. It may be that a certain state of disintegration is required on the part of the alumina and the silica, so that their proximate elements shall be neither too fine nor too coarse; or it may be that the silica, in combining with the alumina, separates the atoms of the latter to precisely those distances required for the development of the property; or, lastly, the presence of a small portion of animal or other organic matter in clay may have something to do with this remarkable property."

off in the smoke. This is a critical stage of the operation. As the combined water is expelled the particles of the clay begin to settle together and the pores to close up; and if the heat be too quickly raised this process goes on so rapidly at the outside of the bricks that the gases evolving in the centre find it difficult or impossible to force their way out. In this case the imprisoned gases will distend or "bloat" the bricks and perhaps ruin their shape altogether. This is more apt to occur in the burning of large paving blocks or bricks of extra size. The chemical changes are accompanied by corresponding alterations in the physical conditions of the clay. The expulsion of the water has brought about a shrinkage in the size of the bricks, which are now denser, harder and stronger than before. Their weight is subject to no further reduction. If the contents of the kiln have safely passed through this ordeal, there is usually little further need for fear in the burning. The heat is again raised, and vitrification shortly begins to set in whereby the various constituents of the clay are chemically combined into one compound silicate. This process may be regarded as the initial stage of fusion, but must not be carried to the actual point of fusion, otherwise the clay will melt and run entirely out of shape. As the heat becomes nearly as great as the clay can bear, the structure of the latter is so changed that instead of exhibiting a rough, stony fracture, the clay will break with sharp edges like glass, and will no longer absorb water.* After vitrification occurs, the kiln must be gradually cooled down previous to the removal of the brick. From two to four days are required for "water-smoking," from four to six for burning proper, and from three to five for cooling. If cooled too rapidly, the bricks become glassy and brittle, while by allowing the heat to slowly subside, they are toughened, and, as it were, annealed. Indeed, the term "annealed brick" has been proposed as a substitute for "vitrified brick," as being more descriptive of the essential quality of a first-class article. The word "vitrified" conveys the idea of a glassy, and consequently a brittle product, while the fact is that good

* The degree of heat required to bring about these changes Mr. Orton found to vary between 1800° F. for shales and 1920° F. for fire-clay, the product being paving bricks. The temperature of open hearth steel in the furnace before being tapped for pouring was 2660° F.; of mill-iron as it ran from furnace to casting-bed 2225° F.; inside of boiler fire-box 2175° F.; of another fire-box 2295° F. The *Clay-Worker*, April, 1894, p. 447.

paving bricks, though "vitrified" in the sense of being rendered impervious to moisture, or nearly so, are tough and very difficult to break. As a matter of fact, it is possible to produce a paving brick of fair quality without vitrification. Where the raw material approaches a fire-clay in its composition, it may be difficult or incapable of fusion, and yet may yield a paving brick suitable for a warm climate and for moderately heavy traffic. Bricks made in certain parts of West Virginia from clays of this kind have given good satisfaction. A degree of vitrification is however requisite for a rigorous climate like our own, as a brick which would absorb any appreciable quantity of moisture would soon be shattered by the keen frosts of our winters.

Qualities of Paving Brick.

A first-class paving brick will resist a file or emery-wheel almost as effectually as a piece of cast-iron. It should have a specific gravity of about 2.25, and be capable of sustaining a crushing strain of about 12,000 pounds per square inch. Bricks of fair quality will vary in specific gravity from 2.03 to 2.41, and in crushing strain from 9000 to 13,000 pounds per square inch. The crushing strain of granite varies from 5000 to 21,000 pounds per square inch. The test for crushing strain, however, is difficult to apply, and unless made under definite conditions is uncertain in result. The transverse strength of a brick, viz., the weight it is capable of sustaining in the centre while the ends are resting on supports, is more easily ascertained, and representing as it does both the compressive and tensile strength of the material, probably indicates more nearly the value of the brick for actual wear in the street. A standard brick should exhibit a transverse strength of at least 1600 pounds to the square inch.

The percentage of water absorbed by a paving brick is an important test of its quality. The best bricks will not take in more than 2 per cent. of their own weight after an immersion of three days, while a common red building-brick which has a specific gravity of 1.82 per cent. will absorb as much as 15.13 per cent. of its own weight in the same time. The ratio of absorption, however, is usually greater than 2 per cent., and in some cases runs as high as 3 and even 5 per cent., though brick of this latter quality should be looked upon with suspicion and as scarcely suitable for use in northern climates. The presence of caustic lime in a

brick is also revealed by the immersion test. Caustic lime has a great affinity for moisture, and if it be present it will absorb the water and break or crack the brick, or will form "poppers" on the surface.

It is customary to test paving brick for its resistance to abrasion by placing the specimens in a foundry-tumbler with pieces of cast-iron, and after submitting them to so many hours' friction at a given number of revolutions per minute, to calculate the loss as compared with the original weight. No standard of comparison has yet been fixed for this test, but it is useful in determining the resisting powers of bricks of different makes, or of bricks delivered on a contract as compared with the samples.

Tests of Ontario Paving Bricks.

Vitrified bricks from some of the shales and clays of Ontario, were recently subjected to a test at the School of Practical Science, Toronto, by Mr. C. H. C. Wright, B.A.Sc., lecturer in Architecture, the object being to determine (1) their powers of absorbing moisture, and (2) their transverse strength. The bricks so tested were made from the Hudson River shale at the Don and Mimico, and the Medina shale and clay at Hamilton. Along with these were submitted for purposes of comparison several bricks of well-known manufacture in the United States. The results were highly gratifying, especially at the present experimental stage of the industry here, when it is not to be expected that the best methods have been found or the greatest skill in manipulation acquired. The test which was indeed surprisingly favorable to the Ontario bricks, goes far to show not only that we have here the right material on which to base the manufacture, but also that Ontario makers may hope with time and experience to produce an article which will withstand competition from any quarter. In ascertaining the powers of absorption of the various samples, or rather their capacity to resist the penetration of water, the bricks were placed in a drying chamber and subjected to heat until they ceased to lose weight, thus depriving them of all their hygrometric moisture. They were then immersed in water, and weighed at intervals of three, five and fourteen days, with the results as noted in the respective columns of the table given below. It will be observed that much the larger proportion of water taken up was in every instance during the first period of three days, and that there

was comparatively little increase in weight after the fifth day. In the absorption test the Syracuse brick, which proved itself almost impervious to water, took first place, the Ontario samples ranking second, third and fourth, and showing a marked superiority over two of the American bricks. The possession of high non-absorptive properties in a brick is good evidence of thorough vitrification, and is a prime requisite in a climate like our own. In more southern regions, where the temperature is uniformly higher, this quality probably has not the same importance, but the effect of our keen frosts on a pavement of water-soaked brick would be very disastrous.

The transverse strength of the bricks was preferred as a test to their crushing strain, which is the one usually taken, for two reasons (1) it is more likely to be a true index of the quality of the brick, and (2) it more nearly represents the conditions of actual wear. In the usual method of ascertaining the crushing strain a 1- or 2-inch cube is cut from a corner of the sample and subjected to the test. In hammering, chipping and otherwise dressing this small cube to the perfectly exact dimensions required, there is considerable risk of weakening it by starting flaws or cracks, not discernible to the eye, yet of sufficient importance to vitiate the result of the test. This objection does not apply to the test for transverse strength, which is made on a machine constructed for the purpose by placing the specimen on rests near the ends and then applying pressure in the centre until it gives way. The weight registered by the machine at the instant of yielding is the total pressure applied, from which the pressure sustained per square inch is easily calculated. A pavement is very rarely called upon to withstand anything like a pressure of 10,000 or 12,000 pounds per square inch, which is about the crushing strain capacity of good paving brick, and in any case it is evident that the wear due to dead weight pressure is very small as compared with that caused by impact and friction. The transverse strength test, on the other hand, indicates the power of a brick to resist pressure and at the same time to withstand the flattening out or stretching tendency induced by a superincumbent weight. In this test the Syracuse brick again headed the list, the Ontario samples standing second, fourth and sixth. The average transverse strength shown by the seven samples was 2659 pounds per square inch, while the average of the three Ontario bricks was 2681 pounds per square inch. Good

quality paving brick is expected to stand a transverse strain of not less than 1600 pounds per square inch, so that every one of the samples tested was more than equal to the requirement in this respect.

The following table shows the result of the test for absorption:

Brick No.	Weight in Pounds.				Total increase. Pounds.	Percentage of increase.
	Dry.	3 days in water.	5 days in water.	14 days in water.		
1	6.908	7.000	7.027	7.047	.139	2.01
2	7.344	7.375	7.375	7.375	.031	.42
3	6.078	6.094	6.098	6.109	.031	.51
4	5.984	6.078	6.094	6.109	.125	2.08
5	4.625	4.625	4.627	4.627	.002	.04
6	7.000	8.068	8.738	8.750	1.750	25.00
7	6.891	7.862	7.987	7.901	1.010	14.65

In the test for transverse strength the bricks were placed on edge, or with the narrow side up; and the usual formula for determining the modulus of rupture was applied, viz.: $f. = \frac{3wl}{bh^2}$, where $w =$ centre load in pounds, $l = \frac{1}{2}$ span in inches, $b =$ breadth, and $h =$ height. The following table gives the results, and also the size of the bricks in inches:

Brick No.	Transverse strength. Pounds per square inch.	Size of Bricks. Inches.
1	1793	2.525 x 4.050 x 8.500
2	2549	2.600 x 3.900 x 8.750
3	3703	2.375 x 3.875 x 7.750
4	3134	2.325 x 3.850 x 8.125
5	3972	2.000 x 3.650 x 7.500
6	1948	2.560 x 3.750 x 8.500
7	1515	2.500 x 4.250 x 8.500

ABSTRACTS.

Analytical Chemistry, by E. Waller, Ph.D.

Oxalate Method of Classen. (*Zts. f. Angew. Chem.*, 1894, 507). The method was found to be unsuitable for Mn, Co and Ni, but applicable for Mg and Zn. The method consists in adding neutral $K_2C_2O_4$ in excess, so as to redissolve the precipitate first formed, then adding excess of $HC_2H_3O_2$, boiling, settling, and finally washing with a mixture of H_2O, alcohol and $HC_2H_3O_2$.

Dihydroxytartaric Acid a Reagent for Sodium. Fenton (*J. Lond. Chem. Soc.*, lxvii., 48). The formula of the acid is given as $C_4H_6O_8$, that of the sodium salt as $C_4H_4Na_2O_8$, $2\frac{1}{2}H_2O$. The acid is made by covering crystallized tartaric acid with glacial acetic acid, and oxidizing by Br in glacial acetic. The solution is precipitated by addition of Na_2CO_3. After washing and purifying, the free acid is obtained from the very insoluble Na salt, by Miller's method (ether solution of HCl).

Analysis of Sodium Peroxide. Archbutt (*Analyst*, xx., 3). Dissolving a weighed quantity in water, boiling to destroy peroxide, and alkalimetric titration gives total Na_2O.

In another larger portion dissolving, acidifying, boiling and precipitation with ammonia gives Fe_2O_3 and Al_2O_3, etc.

Different methods for determining the peroxide were tried; the most satisfactory result was obtained by decomposing with water alone in a Lunge nitrometer, after adding a little $Co(NO_3)_2$ or $Co_2(OH)_6$. The sample of which the analysis is given contained Na_2O_2, 90.41 per cent. NaOH., 8.73 per cent. and Al_2O_3 with Fe_2O_3, 0.49 per cent. Available oxygen, 18.52 per cent.

Potassium in Fertilizers. Garrigues (*J. Am. Chem. Soc.*, xvii., 47). The method consists in: 1. Ignition with H_2SO_4 to convert to K_2SO_4 and expel or destroy NH_4 salts and organic matter. 2. Precipitation of sulphate by $BaCl_2$. 3. Removing excess of Ba, etc., by Na_2CO_3. 4. Evaporation with $PtCl_4$ as usual.

The Lindo-Gladding method is stated to give at times irregular results.

Comparative results by the Lindo-Gladding, the Stassfurt, and the Garrigues methods are given.

Arsenic Determinations. Gooch and Phelps (*Am. J. Sci.*, xlviii., 216). It was found that on the addition of strong HCl and some KBr to an arsenate solution and then distilling, the As was reduced, and passed over as $AsCl_3$. In using the proportions of 5 c.c. of As_2O_5 solution, 3 grammes KBr and 5 c.c. conc. HCl and distilling nearly to dryness in a small flask (25 to 50 c.c.), one distillation easily carried over 0.001 gramme As; two sufficed for 0.01 gramme and three for 0.1 gramme. Sb also was carried over.

Telluric Acid. Gooch and Howland (*Am. J. Sci.*, xlviii., 375). Tellurous acid if present should be oxidized previously by the use of permanganate to telluric. The solution is then placed in a distillation apparatus and 3 grammes KBr added. The entire bulk of the solution should be about 50 c.c., of which there should be 10 c.c. of half strength H_2SO_4. CO_2 is passed through the apparatus and the solution boiled—the Br set free being conducted into KI, which is afterward titrated by standard $Na_2S_2O_3$. Test analyses, in which the results were calculated on atomic mass Te = 127, O = 16, gave very satisfactory results.

Separation of Thorium. Dennis and Kortright (*Zts. f. Anorg. Chem.* vi., 35). Potassium hydro-nitride, KN_3, was found to separate Th apparently as $Th(OH)_4$ in perfect purity from a neutral nitrate solution of the earths.

The process is described thus: Brazilian monazite was freed as much as possible by vanning from the menaccanite accompanying it. It was then heated for several hours in conc. H_2SO_4. The residue was added to ice water in small portions—a little at a time—and then allowed to stand for some hours with frequent shaking. The clear solution was then drawn off, and the ice-cold solution at once precipitated by $H_2C_2O_4$. The precipitated oxalates were washed by decantation with hot water (containing 1 per cent HCl) until the wash water gave only a weak reaction for Fe on shaking with KCyS and ether. The oxalates were then dissolved in conc. HNO_3; the major part of the free acid evaporated off, the residue dissolved in water, the solution diluted and precipitated by ammonia. The precipitate was washed free from lime, and dissolved in HCl. H_2S was then passed through the hot solution for four hours: the heat was then withdrawn, and H_2S passed in during the night. The small precipitate formed was filtered off, H_2S was expelled by warming, and the earths were again precipitated with $H_2C_2O_4$. This precipitate was washed with hot water weakly acidified with HCl to remove traces of Fe. The precipitate was dissolved in HNO_3, the most of the free acid removed by evaporation, and the solution after diluting, nearly neutralized by ammonia. To this solution KN_3 was added so long as it produced a precipitate. Tests for the presence of rare earths other than Th in the precipitate gave negative results.

The equivalent was found to be 232.1, 232.7 and 232.4. Ostwald assumes the probable equivalent of Th as 232.4.

Sulphur Compounds in the Air. Oates (*Proc. Lond. Chem. Soc.*, 1894 218), gives the account of attempts to estimate these. No satisfactory method, either as regards reagents or apparatus was found, but the results tend to show that determinations previously published are too low, and that no correct method has as yet been devised.

Sulphur in Copper. Hampe (*Chem. Ztg.*, xiv., 1778). It is found that a part of the S in refined copper exists there as occluded SO_2. The method pursued to obtain the S present as sulphide was to treat the metal (in chips) with cold $CuCl_2, 2NH_4Cl$, which leaves the sulphides undissolved, and in which the sulphide sulphur may be determined. Meinecke (*Fres. Zts. Anal. Chem.*, x., 280), has found that under some conditions some of the sulphide sulphur converts to H_2SO_4. Hampe finds that in

the cold this does not occur, and that sulphide sulphur is always less than total S. The difference is attributed to SO_2.

Determination of Phosphoric Acid. De Roode (*J. Am. Chem. Soc.*, xvii., 43). Molybdate process. Certain results are recorded, from which the conclusions are:

1. That our present method for determining phosphoric acid seems to give results which are somewhat too high.
2. That the results obtained by using a large quantity of substance, and obtaining large precipitates are lower and somewhat more accurate than those obtained where smaller quantities are employed.
3. That somewhat lower and more accurate results are obtained by using a "blank" made by employing a dilute solution of a phosphate, which is also added to each determination in known amount. This "blank," previously determined, being subtracted from the final result.
4. That accurate results, agreeing with those obtained by the use of the blank, are obtained by redissolving the magnesium pyrophosphate, and reprecipitating.
5. That five minutes digestion at 65° C., seems to be sufficient for the complete precipitation of phosphoric acid by molybdic solution.

Phosphoric Acid in Soils. Goss (*O. A. C. Bulletin*, No. 43, p. 58, U. S. Dept. Agric). The method which is minutely described consists in destroying organic matter in a Kjeldahl flask by that method (conc. H_2SO_4 and HgO). After this operation, the material is boiled with HNO_3 to oxidize Fe, and in an aliquot portion of the clear solution the P_2O_5 is separated by molybdate.

Phosphoric Acid. Estimation by Acidimetric Titration of the Yellow Precipitate. Kilgore (*ib.*, p. 100). Managed according to Pemberton's directions (QUARTERLY, xv., 156), the general tendency was to high results, and at times wide variations occurred though the results were generally fairly good. One source of the variations appeared to be from co-precipitation of MoO_3. On using the official molybdate solution (100 grammes MoO_3, 417 c.c. ammonia (Gr. 0.96) and 1250 c.c. HNO_3 Gr. 1.2) and precipitating at 60° C, the variations were found to be fewer.

Determinations of Phosphoric Acid. Kilgore (*J. Am. Chem. Soc.*, xvi., 793). In a solution of crystallized Na_2HPO_4, analyzed by several chemists for the A. O. A. C., the average of the determinations was higher than theory. The suggestion made is that the difficulty is not with the molybdate separation (which was used by many), but in the precipitation of an excess of MgO with the $MgNH_4PO_4$ precipitate.

Phosphorus in the Products from the Metallurgy of Iron. Benazet (*Bull. Soc. Chem.*, xi., 1083). For irons and steels use not over 1 gramme, dissolve in HNO_3 (Gr. 1.2). Add a few drops of HCl, and evaporate to dryness. Take up with 5 or 6 c.c. HCl, evaporate gently to expel free acid, add 30 or 40 c.c. HNO_3, evaporate to about 10 c.c., dilute with an equal bulk of water, and filter off SiO_2. Wash with as little hot water as possible. Concentrate the filtrate to 4 or 5 c.c., and then pour it into 50 c.c. of the molybdate reagent, kept at 45° C. Stir in and

keep it on the water bath at 45° for an hour or an hour and a half, when all will be precipitated. If the amount of arsenic present is small (0.1 per cent. or less), it will not interfere. If it is larger, on the occasion of the first evaporation with HCl, use more HCl, and add 1 to 2 grammes Na_2SO_3 before evaporating, which expels $AsCl_3$. Ores, slags, etc., soluble in HCl are first dissolved in that acid, the solution being treated as above. If insoluble in HCl, fuse with alkaline carbonate with addition of nitrate or chlorate. The water solution from the fusion will contain the phosphate, which had best be separated by addition of a known amount of ferric salt, the content of which in phosphorus is known, and then precipitating with ammonia. Determining by means of Mg precipitation is not recommended. The methods regarded as preferable for small amounts of P are:

1. Weighing the dried yellow precipitate on a tared filter. Wash with cold water acidulated with 1 per cent. HNO_3. Contains 1.63 per cent. P.

2. Calcining the precipitate at 400 to 500 C., and weighing. Wash as before, dissolve through the filter with ammonia, into a weighed capsule, evaporate, and calcine. Meinecke states the precipitate contains 1.764 per cent. P. The author's results indicate 1.8, which factor he adopts.

3. Colorimetric with $SnCl_2$ solution. (Applicable only when the per cent. of P is 0.025 per cent. or less.) Filter through asbestos, wash with a little water, and then pour through the filter a solution containing $SnCl_2$ 12 grammes and HCl 80 c.c. in one litre. A standard solution for comparison is made from a solution of Na_2HPO_4 or $(NH_4)_2HPO_4$ (0.0001 gramme P. per 2 c.c. or 3 c.c.) treated in the same way as the sample. An excess of MoO_3 has no material effect on the test, the coloration given by it with $SnCl_2$ being only a faint yellow. As the blue tint fades slowly, the comparisons should be made at once.

4. Volumetric. Zn reduction. Emmerton method. Boiling the solution with granulated Zn for full thirty minutes to effect complete reduction is advised. The author's experiments lead him to conclude that the Mo compound reduces to $Mo_{12}O_{19}$. The record of comparative analyses by these different methods is given.

Borates, etc. Moissan (*Bull. Soc. Chem.*, xviii., 955). A modification of Gooch's method is proposed in which the H_3BO_3 freed by a little HNO_3 is distilled over with methyl alcohol into a flask containing ammonia. The ammonia solution is poured upon a weighed quantity of CaO prepared as in the Gooch process. The alcohol is evaporated off at 70° C., and the lime holding the B_2O_3 is weighed.

Carbon in Iron and Steel. Lunge and Lwoff (*Stahleisen*, 1894). The conclusions are that the copper ammonium chloride method of solution is superior to the copper sulphate method; the latter treatment, to give accurate results, should he continued for six hours. The chromic sulphuric acid combustion is perfectly satisfactory, provided that at the end of the operation a little H_2O_2 is added.

Kjeldahl Method—Gunning's Modification. Garrigues (*J. Am. Chem. Soc.*, xvi., 795). The best mode of proceeding was found to be: Add the salicylic acid mixture (1 gramme salicylic in 30 c.c. conc. H_2SO_4)

directly to the sample, shaking until the mass is thoroughly wetted. Allow to stand fifteen minutes, and then add 5 grammes cryst. $Na_2S_2O_3$ gradually, a crystal at a time (4 or 5 portions), adding a fresh lot only after the first has dissolved, then add 10 grammes K_2SO_4, and digest, etc., as usual.

Nitrogen in Nitrates. Gantter (*Fres. Zts. Anal. Chem.*, xxxiv., 25). The method of measuring evolved NO by action of H_2SO_4 with the nitrate on Cu was found to give low results with small amounts, but causing H_3PO_3 to act upon HNO_3 (set free by H_2SO_4) affords HNO_2, and if this reacts upon NH_4Cl twice as much N as that contained in the nitrate is evolved, and may be measured in a suitably constructed form of apparatus. The reactions given are:

$$N_2O_5 + P_2O_3 = N_2O_3 + P_2O_5.$$
$$N_2O_3 + 2\,NH_4Cl = 2\,N_2 + 3\,H_2O + 2\,HCl.$$

The proportions recommended are 3 c.c. of a solution (containing not over 0.3 gramme of nitrate), 0.5 gramme crystallized NH_4Cl, 0.5 gramme crystallized H_3PO_3, and at first 2 c.c. H_2SO_4 (2 : 1 by volume) afterwards followed by 5 c.c. of the same. The gas must be collected over NaOH (to absorb HCl). Directions for the management of the reaction in a special form of apparatus devised for the purpose are given.

Metallurgy for 1894, by Joseph Struthers.

Refractory Materials.

Determination of the Refractoriness of Fire-Clays.—By H. O. Hofman and C. D. Demond.—From *Trans. Amer. Inst. Min. Engrs.*, February; *Eng. and Min. Journ.*, April 21st.

Furnaces.

A French Regenerative Gas Furnace.—By Joseph Struthers.—*S. of M. Q.*, January.

Fuels.

Physical Properties of Metallurgical Fuels.—By John Fulton.—*Amer. Manuf. and Iron World*, November 2d.

The Strachan Coke-Oven (Illustrated).—*Eng. and Min. Journ.*, February 17th.

Coking Peat in Sweden.—*Eng. and Min. Journ.*, June 2d.

Coking with Recovery of By-Products.—By John F. Wilcox. Description of the Otto-Hoffman ovens at Recklingshausen, with illustrations of the ovens and the interior of the by-product plant.—*Iron Age*, September 6th.

The Efficiency of Gaseous Fuel.—By F. A. Matthewman. From paper read before the West of Scotland Iron and Steel Institute.—*Eng. and Min. Journ.*, June 16th.

Note on the Taylor Gas-Producer Plant at the Ontario Mill.—By C. A. Stetefeldt.—*Trans. Amer. Inst. Min. Engrs.*, September.

PYROMETRY.

Pyrometry and the Heat Treatment of Steel.—By H. M. Howe.—*Trans. Amer. Inst. Min. Engrs.*, September.

The Uehling and Steinbart Pyrometer (Illustrated).—*Iron Age*, February 22d.

BLAST-ENGINES.

Tests of Tandem Compound Blowing-Engines. Description of engines used at Monongahela Furnace Company, McKeesport, Pa.; accompanied by plan and elevations.—*Iron Age*, June 7th.

CAST-IRON.

Progress of Iron-Making in the South.—By John Birkinbine. A general discussion with reference to labor, fuel, ore, furnace practice, and the economic factors of adjacent land and values.—*Iron Age*, May 31st.

FURNACE CONSTRUCTION.

Suggestions for Building a Modern Blast-Furnace.—By Guy R. Johnson (Illustrated).—*Eng. and Min. Journ.*, October 20th.

The Hawdon and Hawson Blast-Furnace.—Extract from article in *Le Génie Civil*, by Alexander Pourcel. Gives a drawing of the furnace lines as constructed at the Newport Works at Cleveland, England.—*Iron Age*, April 19th.

Increasing the Life of Furnace Linings.—A discussion by John E. Gayley of E. C. Potter's paper on "American Blast-Furnace Practice."—*Iron Age*, July 5th.

Blast-Furnace, on the Capacity and Form of.—William Hawdon (Discussion).—*London Engineering*, July 6th.

BLAST-FURNACE PRACTICE.

Modern Blast-Furnace Practice (Editorial).—*Iron Age*, October 11th.

A Method of Ascertaining the Value of Iron-Ore, Limestone, and Coke in Blast-Furnace Use.—By R. E. Chambers.—*Iron Age*, May 17th.

Calculation of Fuel Charges for the Iron Blast-Furnace. II.—By A. Bjerregaard.—*Iron Age*, February 22d.

The Principal Smelting Reactions of Blast-Furnace Slag Considered on Thermo-Chemical Principles.—By A. D. Elbers.—*Eng. and Min. Journ.*, March 31st.

Magnesia and Sulphur in Blast-Furnace Cinder.—By Frank Firmstone.—*Trans. Amer. Inst. Min. Engrs.*, September.

Liquid Cinder Dumping Car (Illustrated).—*Iron Age*, December 27th.

The Hawdon Slag Machine. This machine is devised for the rapid removal of slag from the blast-furnace. A very good view of the machine as attached to the furnace is given.—*Iron Age*, August, 16th.

The Martin & James Hydraulic Pig Iron Breaker. (Illustrated.)—*Eng. and Min. Journ.*, February 24th.

Apparatus for Breaking Pig Iron.—By John S. Kennedy, Chambersburg, Pa. Illustrated description of apparatus, with sections of cast house, breaking table and elevation of breaking table.—*Iron Age*, August 2d.

IRON ORES.

The Iron Ores of the Mediterranean Seaboard.—By A. P. Wilson. Paper read at the Brussels meeting of the Iron and Steel Institnte.—*Iron Age*, October 25th, November 1st, 15th, 22d.

Iron Ores of East Tennessee.—By W. Kennedy.—*Trans. Amer. Inst. Min. Engrs.*, May.

The Cornwall Ore Hills.—By John Birkinbine. (Descriptive.).—*Iron Age*, November 8th, 15th, 22d.

The Iron Ore Region of Lake Superior. (Illustrated.)—*Eng. Mag.*, December.

The Iron Ores of the Mesabi Range.—By J. E. Sparr. From *American Geologist.—Eng. and Min. Journ.*, June 23d.

CAST-IRON.

Strength and Resistance of Cast-Iron. Abstract of discussion by J. B. Johnson, before the Foundrymen's Association.—*Eng. and Min. Journ.*, August 25th.

Comparison of Strength in Specialty Mixtures of Cast-Iron.—By Thomas D. West.—*Iron Age*, November 1st.

Comparison of Strength in Specialty Mixtures of Cast-Iron.—By Gus C. Henning. Discussion of Thos. D. West's article.—*Iron Age*, November 29th.

Committee on Testing Round and Square Test Bars. Report to Western Foundrymen's Association.—*Iron Age*, November 29th.

Relative Tests of Cast Iron.—By W. J. Keep.—*Iron Age*, December 20th.

Cost of Pig Iron in the Birmingham District.—*Iron Age*, June 7th.

Manufacture of Speigeleisen.—*Sci. Amer.*, September 1st.

FOUNDRY PRACTICE.

Foundry Mixtures Controlled by a Mechanical Analysis. By W. J. Keep. Detailed discussion accompanied by numerous tables illustrating the effect of chemical composition on physical properties.—*Iron Age*, July 12th.

Manganese in Foundry Iron.—By A. P. Bjerregaard.—*Iron Age*, March 22d.

Influence of Silicon, Sulphur and Manganese on Foundry Irons.—By J. B. Nau.—*Iron Age*, March 29th.

The Edgar Hydraulic Moulding Machine. The illustrations show a sectional front elevation, section of valve and the end elevation.—*Iron Age*, June 28th.

Machine Moulding.—By Harris Tabor.—*Iron Age*, December 27th.

The Will Foundry Sifting Machine. (Illustrated.)—*Iron Age*, December 13th.

A Visit to a Stove Foundry. A popular article, with illustrations of the various parts of the foundry.—*Iron Age*, June 7th.

Cupola Practice and Foundry Work. (Discussions.). In Western Foundrymen's Association.—*Iron Age*, April 12th, May 24th, July 12th, August 9th, 30th, October 4th, 10th.

MILL WORK.

Press Working of Sheet Metals.—By Oberlin Smith. Profusely illustrated and descriptive article of press work.—*Iron Age*, April 19th, July 5th, 12th, 26th, August 30th, September 20th, 27th, October 4th.

Rolling Wire Rods Directly from Small Ingots.—Illustrated description of the Haspe Eisen und Stahl Fabrik. From *Stahl und Eisen.*—*Iron Age*, November 1st.

An Intricate Wire-Forming Machine.—Descriptive article fully illustrated by sixteen cuts.—*Iron Age*, June 28th.

The Klatte Method of Rolling Weldless Chains.—Illustrative and descriptive article on the paper read before the Verein Deutscher Eisenhüttenleute, by O. Klatte.—*Iron Age*, August 30th.

Annealing Sheet-Iron.—By Ambrose Beard (Illustrated).—*Iron Age*, January 4th, 11th.

Some Points About Heating Furnaces.—By G. Siewrin.—*Iron Age*, March 1st.

Forging by Hydraulic Pressure.—By Ralph Hart Tweddell (Illustrated).—*Iron Age*, September 6th.

CRYSTALLIZATION OF IRON AND STEEL.

The Crystallization of Iron.—By H. M. Howe.—*Eng. and Min. Journ.*, November 24th.

Do Iron and Steel Crystallize in Service?—By Paul Kreuzpointner.—*Eng. News*, July 19th.

Methods of Preparing Polished surfaces of Iron and Steel for Microscopic Examination.—By J. E. Stead.—*London Engineering*, June 22d.

PUDDLED IRON.

Puddled Iron in Great Britain. Statistics of production showing a gradual dimunition in output. In 1877 there were 9159 puddling furnaces while in 1893 the number had dwindled to 3535 of which only 2350 were in use.

The Total Production of Finished Iron for 1893 is given as follows:

	Tons.
Rails,	10,631
Ship-plates,	115,586
Boiler plates,	31,534
Sheet iron,	186,892
Nail rods,	9,541
Bar iron,	293,489
Angle iron,	107,902
Hoop iron,	100,321
Tee iron,	43,064
Wire rods,	61,868
Strips,	67,298
Rounds and squares,	95,819
Other iron,	135,196
	1,259,141

MALLEABLE IRON CASTINGS.

Malleable Iron Castings.—By S. Bolland.—*Mech. World*, July 6th *et seq.*

Malleable Castings from Coke Pig-Iron (Illustrated).—*Iron Age*, December 6th.

STEEL.

Steel Manufacture in the South.—By C. A. Meissner, Birmingham, Ala. Discussion of manufacture and product.—*Iron Age*, August 23d.

Ohio Steel Company. Description with full page illustration of general plan of works.—*Iron Age*, August 16th.

American *vs.* European Steel (Discussion).—*Iron Age*, April 26th, May 3d, July 12th.

The Cost of Making Steel Billets and Slabs. Tabulated details and compositions of products.—*Iron Age*, August 2d.

The Heat Treatment of Steel.—By H. M. Howe.—*Trans. Amer. Inst. Min. Engrs.*, May.

The Casting Temperature of Soft Steel.—*Iron Age*, October 18th, 25th.

Methods of Cooling Steel.—By E. T. Clarage.—*Eng.*, October 13th.

The Walrand-Legenisel Steel Process.—By George J. Stead. Abstract of paper before the Brussels Meeting of Iron and Steel Institute.—*Eng. and Min. Jour.*, September 15th.

BESSEMER STEEL.

The Bessemer Steel Industry, Past and Present.—By Sir Henry Bessemer.—*Eng. Rev.*, July.

The Magnitude of the Bessemer Steel Industry.—By Sir Henry Bessemer. From the *Engineering Review*. By direct comparisons with objects of given dimensions, the author endeavors to impress the great output of this industry. As an illustration, the World's production for 1893 was 10,500,000 tons, which, if made into a wall 5 feet thick and 80 feet high, would be 100 miles in length.—*Iron Age*, August 16th.

The Bessemer Steel Industry and the Nail Manufacture.—By Sir Henry Bessemer. From the *Engineering Review*. Illustration showing the relative size of a column of Bessemer steel 100 feet in diameter and 6684 feet high, being the production of Bessemer steel for 1892, with St. Paul's Cathedral, etc.—*Iron Age*, October 4th.

The Meyer Recarburizing Process.—An article by Dr. H. Wedding, contributed to *Stahl und Eisen*. Describes the method of working and gives a number of tables showing the different amounts of carbonaceous bricks added to produce steel of varying grades.—*Iron Age*, June 28th.

American *vs.* European Basic Bessemer Steel.—By J. B. Nau.—*Iron Age*, April 26th, May 3d.

Sulphur in the Basic Bessemer Process.—By J. E. Thompson.—*Iron Age*, January 19th.

OPEN-HEARTH STEEL.

The Manufacture of Open-Hearth Steel in Sweden.—By Erik G.

Odelstjerna, Filipstad, Sweden. Detailed description of Swedish practice. Illustrated by ten drawings of producers and furnaces.—*Iron Age*, July 19th and 26th.

The Manufacture of Steel in the Open-Hearth.—By James Alexander Lencanchez. Description and discussion.—*Iron and Coal Trades*, London, August 24th.

Report on the Working of a Siemens Furnace.—By I. L. Stevenson, Chicago, Ill. Gives complete detail as to the working of the furnace, with tabulated compositions of charge during the heat. Complete description of various charges for different qualities of steel are given in pleasing tabular detail. Furnace construction and drying are also discussed.—*Iron Age*, August 2d.

Open-Hearth Steel Furnaces (Illustrated).—From *Trans. Amer. Inst. Min. Engrs.*, February; *Eng. and Min. Journ.*, May 12th.

Open-Hearth Steel in Sweden.—By E. G. Odelstjerna (Illustrated).—From *Trans. Amer. Inst. Min. Engrs.*, February; *Eng. and Min. Journ.*, July 14th and 21st.

Open-Hearth Steel. Discussion and illustrated description, giving drawings of numerous furnaces (5 parts).—*Iron Age*, November 15th, 29th, December 13th, 20th, 27th.

Basic Open-Hearth Furnace.—By G. L. Luetscher (Illustrated).—*Iron Age*, February 22d.

Sebenius's Rotating Ingot Molds.—By J. L. Sebenius (Illustrated).—From discussion by Prof. R. Akermann on the "Bessemer Process in Sweden," before the American Institute of Mining Engineers.—*Eng. and Min. Journ.*, April 21st.

Segregation in Iron and Steel.—From discussion by American Institute of Mining Engineers, February, 1894 (Illustrated).—*Eng. and Min. Journ.*, April 28th, May 5th.

Surface Defects in Ingots.—By J. S. Robeson.—*Iron Age*, December 13th.

The Present Status of Case-Hardened Armor.—By Capt. W. T. Sampson. From paper read before the Society of Naval Architects.—*Iron Age*, December 6th.

SLAGS.

Production of Basic Slags for Fertilizers. (Discussion.)—*Iron Age*, June 7th.

Slag Cement Experiments.—By R. W. Mahon. *Journ. Frank. Inst.*, March.

The Economic Uses of Blast-Furnace Slags.—By A. D. Elbers.—*Eng. and Min. Journ.*, April 28th.

The Utilization of Waste Heat Contained in Slags from Smelting Furnaces.—By John Howell and E. A. Ashcroft. From Australian Institute of Mining Engineers.—*Eng. and Min. Journ.*, July 21st.

COPPER.

Preliminary Tests on the Strength of Copper. Extract from *Mittheilungen*, 1894.—*Iron Age*, November 22d.

The Fairfield Copper Company.—By Maurice Barnett.—*Eng. and Min. Journ.*, September 15th.

The Vicuna Copper Smelting Furnace.—By A. O. Vicuna. (Illustrated.)—*Eng. and Min. Journ.*, June 9th.

Methods of Copper Smelting in Japan.—*Eng. and Min. Journ.*, April 21st.

The Microscopic Metallurgy of Copper Alloys.—By M. Guillemin. *Eng. and Min. Journ.*, July 7th.

SILVER AND LEAD.

American Practice of Silver Lead Smelting.—By W. R. Ingalls. (Illustrated.)—*Eng. Mag.*, March.

The Brown Horseshoe Furnace. (Illustrated.)—*Eng. and Min. Journ.*, May 12th.

The Manganese Slags of Tombstone, Arizona.—By John A. Church. *Trans. Amer. Inst. Min. Engrs.*, October.

Composition of Lead Slags.—By T. S. Austin. (Illustrated.)—*Eng. and Min. Journ.*, January 27th.

Fire Assay for Lead.—By M. W. Iles.—*S. of M. Q.*, July.

GOLD.

The Allotropism of Gold.—By Henry Louis.—*Trans. Amer. Inst. Min. Engrs.*, May.

Furth's Experiments on Amorphous Gold.—By Henry Louis.—*Trans. Amer. Inst. Min. Engrs.*, September.

The Murphy Gold Process.—By J. G. Murphy.—*Min. and Sci. Press*, September 22d.

The Cyanide Process.—By W. H. Vergre.—*Eng. and Min. Journ.*, June 9th.

The Cyanide Process in the Transvaal Mines.—By W. Feldtman. (Illustrated.)—*Eng. and Min. Journ.*, August 4th and 11th.

Electrical Precipitation From Cyanide Solutions.—By A. Von Gernet. *Eng. and Min. Journ.*, November 3d.

The Modern Practice of Chlorination.—By H. J. Jory.—*Eng. and Min. Journ.*, January 27th.

Chlorination of Gold Ores.—L. D. Godshall.—*Eng. and Min. Journ.*, January 6th and 13th.

The Refining of Gold Sulphides Produced by the Precipitation of Gold from Chlorine or Bromine Solution with Sulphurous Acid and Hydrogen Sulphide.—By Werner Langguth.—*Trans. Amer. Inst. Min. Engrs.*, May.

Gold Milling at the North Star Mine, Grass Valley, Nevada county, California.—By Emile R. Abadie.—*Trans. Amer. Inst. Min. Engrs.*, May.

Gold Milling in Australia.—By T. A. Rickard.—*Eng. and Min. Journ.*, February 3d.

Melting and Refining Gold Bullion.—By H. Van F. Furman.—*S. of M. Q.*, November.

ZINC.

Experiments with Zinc Ores in a Blast Furnace.—By H. Hunike, —*Eng. and Min. Journ.*, September 15th.

The Direct Production of Zinc in the Blast-Furnace.—By W. Hemple. From *Berg und Hüttenmannische Zeitung.—Eng. and Min. Journ.*, June 2d.

Galvanizing.—By M. P. Wood.—*Iron Age*, December 13th.

ALUMINUM.

The Manufacture and Industrial Value of Aluminum Alloys.—By J. H. J. Dagger.—*Journ. Soc. Chem. Ind.*, January 31st.

Aluminum Bronze.—By R. Waldo.—*Trans. Amer. Inst. Min. Engrs.*, September.

Aluminum, Properties and Uses of. Abstract of Report of A. E. Hunt for *Mineral Resources of the United States*, for 1892.—*Eng. News*, February 8th.

Aluminum, Its Properties and Uses.—*Iron Age*, January 18th, 25th.

NICKEL.

Present Status of the Nickel Industry.—By W. L. Austin.—*Eng. Mag.*, November.

ALLOYS.

The Influence of Varying Temperature on Metals.—By M. Rudeloff. Tests were made on wrought iron, open-hearth steel, copper, Delta metal (rolled), Delta metal (cast), 4 per cent. Manganese bronze, 15 per cent. Manganese bronze, at varying temperatures from 14 degrees Centigrade to 400 degrees Centigrade. The properties studied consisted of modulus of elasticity, limit of proportionality, limit of stretch, breaking load, elongation per cent., and contraction of area. The data is tabulated and graphical charts are given of the varying effects. —*Iron Age*, May 24th.

Researches on the Properties of Alloys.—By W. C. Roberts-Austin. —*Eng. and Min. Journ.*, January 20.

ELECTRO-METALLURGY.

Electro-Metallurgy of Gold and Silver.—By A. L. Eltonhead. Theoretical Discussion.—*Proc. Eng. Club*, Philadelphia, November.

Electric Smelting in Germany. Description of methods used.—*Eng. News*, July 12th.

Electro-Metallurgy.—By A. E. Hunt. A popular and descriptive article.—*Eng. Mag.*, June.

The Extraction of Copper from Alloys by Means of Electrolysis.—From Dr. Carl Schnabel's Handbook.—*Australian Mining Standard*, No. 24, Part I.

Electro-Metallurgy. (Welding).—By B. A. Dobson.—*London Engineering*, August 3d.

BOOK REVIEWS.

THE ORE DEPOSITS OF THE UNITED STATES. By James F. Kemp, A.B., E.M., Professor of Geology in the School of Mines, Columbia College. Second Edition. Revised and Enlarged. New York and London. The Scientific Publishing Company, 1895.

The early appearance of a second edition affords an index of the estimate placed upon Professor Kemp's work. It shows, moreover, not only that the book is in itself a satisfactory piece of work, but also that it supplies a real need. Unfortunately, in these days of literary fecundity this is by no means always the case.

As now presented, the book differs from the original edition in the way of expansion rather than of alteration. Slight changes have been made where experience or more extended investigation has rendered them necessary; but these modifications are inconspicuous as compared with the amount of new material added. As stated in the preface, this reaches in the aggregate about fifty pages, besides a number of illustrations.

Of this new material a portion is derived from the author's own field work, particularly in the cases of the Adirondack and Lake Superior iron ores, the New Jersey zinc deposits and the nickel deposits of Lancaster county, Pa., Anthony's Nose, N. Y., and Sudbury, Canada.

Notable among the material derived from the recent investigations of others, is the summary of the brilliant papers of Vogt upon the formation of certain ore deposits by magmatic differentiation. The rationale of the process is outlined in the chapter on classification, and it is cited as a probable explanation for some of the ores of iron and of nickel. While the validity of this explanation of some ores scarcely admits of doubt, it would seem that our present knowledge hardly justifies the emphasis placed upon Soret's principle as the explanation of the magmatic differentiation. There are two distinct questions involved; one, are ores formed by magmatic differentiation? the other, is magmatic differentiation accounted for by Soret's principle? Granting that the former question is answered in the affirmative, the latter is still open for discussion, with strong arguments for the negative.

Special attention is also given to the extremely valuable (if somewhat dogmatic) paper of Posepny, with a summary of its more general and important features.

Besides these additions bearing chiefly upon broad genetic problems, much new material is incorporated with the descriptions of specific deposits. The New Jersey zinc deposits and the Sudbury nickel ores are important instances. In the case of the former the recently ascertained structural relations are described, while the author states his views as to the formation of the ore body by the circulation of solutions stimulated by igneous intrusions.

The description of the Sudbury district though transcending the limits of the title of the book, is justified by its economic importance

and its scientific interest. For these deposits afford not only a great amount of nickel, but also an excellent example of the magmatic concentration of ores.

Instances of similar additions might be greatly multiplied, but the foregoing will serve to indicate in what way the second edition differs from its predecessor.

As to the value of the work as a whole it is hardly necessary to speak, after the cordial reception given to it when first published, less than two years since. Of its many admirable features perhaps the more salient are: an excellent discussion of the general principles underlying this branch of science; the adoption of a rational classification based upon genetic relations; a thorough description of a few types of each class to which all similar occurrences may be referred; a convenient system of arrangement; and, finally, an extensive bibliography.

The last feature is of the utmost importance and will be particularly appreciated by those who find in this volume new incentives to carry on such investigations of our ore deposits as are shown by it, in many cases, to be sorely needed. To stimulate such investigations is one of the objects for which the book is written, and there can be little doubt that it will succeed in this, as well as in affording a valuable text-book and an indispensable work of reference.—C. H. S., JR.

ELEMENTS OF MINERALOGY, CRYSTALLOGRAPHY AND BLOWPIPE ANALYSIS. By Alfred J. Moses, Adjunct Professor Mineralogy, Columbia School of Mines, and Charles Lathrop Parsons, Professor of General and Analytical Chemistry, New Hampshire College. New York: D. Van Nostrand Co. 1895. Pp. vii. and 342. Figs. 336. $2.

Professors Moses and Parsons have sought in the above work to present a concise summary of the three branches mentioned in the title. The endeavor has evidently been consistently and continually made to emphasize the most important points that a man of affairs, an engineer, chemist, or college student would wish to learn regarding minerals. No one can carefully read these pages without feeling convinced that this plan has been admirably and successfully carried out.

The division of space is good, 76 pages to Crystallography, 44 to Blowpipe Analysis, 222 to Mineralogy proper. The schemes of blowpipe analysis are clearly arranged and well elaborated, and the tables for the determination of minerals given at the close, are very convenient.

The difficult branch of this subject for most students to grasp is beyond question, crystallography. More often than not this is due to the fact that it is not clearly and definitely presented. It is not essentially difficult, but on the contrary, its simple and beautiful principles and relationships, once grasped, follow one another in such logical order, that they almost intuitively work themselves out in the mind of the reader or student. In numberless instances they have furnished one of the keenest and most elevated of intellectual pleasures to those who are not professional mineralogists and they cannot fail to command the admiration of all lovers of the orderly results of natural laws. The presentation in the work before us is very clear and impresses us as much superior to the other elementary works in English. The principle of symmetry is wisely used in the definitions of systems and forms, for this is the one that furnishes much the most rational basis of distinctions. It strikes us that it

would have been even better yet had the authors abandoned all mention of *equality* of axes, and rested on symmetry alone for definitions, because in forms of two or more faces, actual equality of intercepts is only a theoretical possibility. But it must be admitted, that the idea of equality or inequality of parameters is an old one and has always been the chief reliance of elementary books, however indefensible on a mathematical basis.

In the treatment of blowpipe analysis, the results of many years of teaching are manifested and the facts are presented in a striking and convenient way. The same is true of the descriptive portion of the work under each mineral. An arrangement has been adopted which throws into strong relief the essential distinctions. The only portion of the descriptive matter to which one might take occasional exception will be found under the head of "Remarks" and relates to the derivation or origin of minerals. For instance, it is stated on page 139, "Pyrrhotite is probably formed by the smelting of pyrite out of contact with air;" whereas pyrrhotite is a direct crystallization either from a fused magma, or else from a solution with no preliminary pyrite. The nickel contents of pyrrhotite are much more reasonably attributable to associated pentlandite or polydymite than to millerite which always appears as secondary crusts. Pentlandite almost deserves mention in this connection for some of the deeper workings at Sudbury are showing considerable. Petrographers would hardly admit in general that hornblende (p. 292), forms in igneous magmas that cool more slowly than those with pyroxene, it being really impossible in nature to draw any such inference. The conclusion is only suggested by artificial experiment. Vesuvianite, p. 300, and andalusite, p. 303, can hardly be called igneous minerals, both being due to contact metamorphism in almost all cases, the former in limestones, the latter in slates. It would have been well too, in connection with rock study, if the authors had used the term plagioclase for the collective triclinic feldspars, p. 282, for that is now widely used by petrographers. Despite, however, these minor slips, the book in its larger features, and in its entirety is a very creditable piece of work indeed, and ought to find a wide field of usefulness in our colleges, technical schools and with the general public interested in the branches which it presents.

J. F. K.

The twelfth edition of the general Sextennial Catalogue of Columbia College has been issued. The volume contains six hundred and twenty-five pages large octavo, and includes the names of graduates of the college and of all its schools with a statement of the degrees and public offices held by graduates and the addresses of over seven thousand living alumni. Special efforts have been made by an energetic committee to secure accurate information, and the larger part of that contained in the catalogue has come from the individuals themselves. It contains a much more accurate list of graduates of the School of Mines, who are not members of the Alumni Association, than that body has been able to secure, which gives it special value among those especially interested in that department. As a frontispiece, opposite to the title page, is a reproduction of the first catalogue of old King's College from the year 1758 to 1774, which is easily included within two facing pages of an

octavo sheet. Very interesting historical notes, covering the important events in the college history from 1754 to 1893, and the list of college officers, including the governors, trustees, etc., occupy a space of seventy-four pages. It is interesting and instructive to see how large a number of persons have been thus identified with the conduct of the institution. Then follow the list of graduates in arts, in medicine, in law, in science and the list of graduates holding higher and honorary degrees. At the end is a locality index and index to officers and an index to graduates, which make the extensive lists thoroughly useful. It will at once suggest itself that this locality index will enable any graduate in any part of of the United States to ascertain at a glance what Columbian men are to be found in his neighborhood, and might be made the means of fostering a still more earnest college sentiment among those who own Columbia College as their Alma Mater.

It will be readily understood that both the preparation and the printing of a book of this magnitude has proved a costly undertaking to the college, so that it is impossible to distribute it gratuitously. It appears in two forms: In plain paper binding it can be had for $1, and in a neat blue cloth binding for $1.50. The committee in charge of its issue will be very glad to foster a desire for the possession of this volume among the alumni, both for the sake of the college feeling it should encourage and for the help which its sale among the alumni will render to the committee in bearing the burdens of its issue. A copy will be mailed on receipt of the price, and as many as possible are earnestly requested to give this matter their attention. Communications should be addressed to J. H. Van Amringe or John B. Pine, Committee on General Catalogue, Columbia College.

BULLETIN OF ALUMNI AND COLLEGE NEWS.

The Board of Managers of the Association of the Alumni has appointed a special committee of eleven which, under the powers conferred upon it, has added to its numbers from the association at large, and now consists of fifty. The function of this committee is the enlisting of the interest of the alumni individually to secure from their friends and those of the college such increase in the endowment and equipment of the school as shall enable it fittingly to start upon the career of usefulness which should open before it on the new site. The members will receive shortly from this committee a document which will present most fully the needs of the crisis and the methods by which it is sought to meet them, but this announcement is made so that the graduates may be assured that this matter is receiving full and careful attention.

There has been a growing feeling ever since the University idea has taken shape at Columbia, that in its relations to the community in which it labors, a greater service could be rendered by the graduates if they could be brought together for a purpose of common interest. The large body would then command an influence which in their smaller organizations they could not secure individually.

On the other hand there were obviously certain advantages and functions which were permitted to the individual organizations, which would be lost if an attempt were made to gather all alumni into one heterogeneous body.

While this matter has been before the minds of the managers of the Alumni Association of the School of Mines for some years as a matter of possible future policy, it has been brought to a decisive head by the necessity now imminent upon the college, to interest its community in the enormous undertaking of providing for itself, by their aid, the accommodations required when the move is to be made to the new Bloomingdale site. Tentatively, and to sound the views of the different associations on this point, conference committees of the associations in the three schools, which have such an organization, were appointed last autumn and arranged for a joint meeting, upon the result of which the policy of further action was to be based. This meeting was convened November 16th at the building of the American Society of Fine Arts, the occasion being an opportunity to inspect the drawings of projected buildings at the new site, and a model in plaster of the building to be devoted to the college library. Nearly 450 persons were present, and at the close of a pleasant little collation addresses were made by the president of the college and representatives of the several schools represented by associations in the gathering.

The success of this meeting warranted the conference committees with the indorsement of their respective boards behind them in preparing and submitting to their several associations a proposed basis for the federation of the several alumni associations for purposes of common service to the college. This federation involves a representative body called the University Alumni Council, and the question of the approval by the graduates of the School of Mines of this proposed federation was

a matter of business at the annual meeting of the association in New York City December 28th.

The scheme of federation preserves for the Association of the School of Mines, all the features which have been found successful in the past, and adds to all that the association has hitherto had, an organized method and channel for bringing the influence of the association to bear upon the large questions which are before the association and the university at this time.

The form of agreement of the alumni associations proposing to enter into this compact, reads as follows:

From the report of a joint committee of the Association of the Alumni of Columbia College, the Association of the Alumni of the College of Physicians and Surgeons, the Alumni Association of the School of Mines of Columbia College.

"First. Upon the adoption of this agreement there shall be established a standing committee designated 'The University Alumni Council of Columbia College,' composed of representatives of the above named associations.

"Second. Each of the associations shall, as soon as practicable after the adoption of this agreement, elect five representatives to serve for the term of one, two, three, four and five years respectively, from the date of its next annual meeting; and shall thereafter, at each annual meeting, elect one representative who shall serve for the term of five years.

"Third. It shall be the duty of the Council, through meetings and by such other means as it deems proper, to extend the knowledge of the university and its work; to establish closer relations between the alumni and the university, and to co-operate with the President and Trustees of Columbia College in carrying into effect such measures as, in its judgment, will tend to promote the interests of the university and its several schools.

"Fourth. The Council may, from time to time, enlarge its membership by the admission of representatives of other associations of the alumni of any of the schools of Columbia College; but no school shall be represented by more than one alumni association.

"Fifth. The Council shall adopt by-laws for its own government, and shall have and exercise such further powers as shall be from time to time conferred upon it by all the associations represented.

"Sixth. No association shall be liable for any expenditure incurred by the Council in excess of the amount appropriated by such association.

"Seventh. This agreement shall not be altered except by the consent of all the associations represented, and any association shall have the right to withdraw on giving six months' previous notice to the others."

THE ARCHITECTURAL DEPARTMENT.

The instruction in design has been reorganized this year, so as to secure greater coherence in the work of the successive years which now forms a connected series of carefully arranged progressive problems culminating in the thesis work. The first class remains under the joint instruction of Prof. Ware and Mr. Harriman. Mr. J. R. Pope ('94) is in charge of the second class, to whom are given problems in elementary composition with the orders, and in rendering the same in India ink

preparatory to the third year work. The problems for the third year, while mainly concerned with exterior design in order to develop the powers of architectural expression of the students, involve also a certain amount of planning and interior composition. In the fourth year planning predominates, the problems assigned being buildings of considerable importance and complexity of requirement. The instruction in design in both the third and fourth years is in the hands of Prof. Hamlin.

The travelling class for the study of the Renaissance monuments of Italy, organized by Prof. Hamlin last spring, sailed for Naples *via* Genoa on the 26th of May. Three months were most profitably and delightfully spent in visiting the places set down in the itinerary for that period. The class separated in September, as the individual plans of several of the members and the desire to visit localities not embraced in the itinerary, made it inexpedient to attempt completing the trip on the original lines. The three months spent together were thoroughly enjoyed, and no mishap or *contretemps* of any kind occurred to mar the pleasure of the party, except a slight indisposition of a few days in the case of one member, who found in it a good excuse for a few days' visit to beautiful Vallombrosa, where he was perfectly restored. The summer's heat was less intense than that reported from home, and the sanitary record of the class was a remarkable one, especially when one considers the radical change in food, drink and habits of life involved in a three-months' stay in Italy.

In Rome, as a result of the kind offices of Hon. Wayne MacVeagh, our Ambassador, the Hon. Bacelli, Minister of Public Instruction, bestowed upon the class the signal favor of appointing an official architect to guide and assist the party in their visits to public monuments in the city. A similar courtesy was extended them in Florence and was again offered in Venice, but declined as quite unnecessary where the monuments to be visited were so accessible. The Venetian Director of the Office of Public Monuments, as well as the Mayor of the city, granted to the members of the class free passes to all the public collections and monuments, national and civic; and here, as in Rome and Florence, these official courtesies led to other favors from directors of museums, civic authorities, professors of archæology and the like, whom the class met in the course of its visits. Prof. Lanciani, in Rome, was particularly kind, devoting several afternoons to visit with the classes; the civic museum in the botanical gardens, the interior of the Arch of Constantine (where a member of the class discovered a hitherto unknown chalk inscription scribbled by Michael Angelo on the stones in 1494), the roof of the Lateran Basilica, and the Pantheon were all visited in the delightful company of Prof. Lanciani. The cities visited were in the following order: Naples, one week; Caserta, Rome, four weeks; Caprarola, Viterbo, Orvieto, one day each; Perugia, three days; Arezzo, one day; Florence, three weeks; Prato and Fresole each took a half day; at Sienna four days were spent; at Lucca two days, and thence, *via* Pistoia, Bologna was reached, where four days were delightfully passed; three days at Ferrara and one at Ravenna brought the class to Venice, where at the end of three weeks the members of the class scattered in various directions. Prof. Hamlin continued his journey eastwards via Corfu, Patras and Athens to Constantinople, where his interest was divided between the Sidon sarcophagi, the effects of the recent dis-

astrous earthquake, and the Byzantine monuments. Returning *via* Vienna and Paris, the schools of architecture in these cities were visited and their methods studied. New York was reached on November 15th.

There were in Paris at the time of Prof. Hamlin's visit nine Columbia graduates in architecture, either already in the Ecole des Beaux Arts or completing their preparations for the next examinations. Of these four belong to the class of '90, three to '91 and one each to '92 and '94. Besides these there were four recent special students from the department and one undergraduate preparing for the same examinations. Totten, '91, one of the McKim Fellows of 1893, was also in Paris. Temple, '91, this year's Columbia Fellow, will study in Rome for the present. Aldrich, Reynolds and Brooks, of '92, are making tours for architectural study in Europe.

The two McKim Fellowships in Architecture have been at the request of their founder consolidated into one Fellowship of the value of $2000, to be held by the winner for two years. Of this time ten months must be devoted to studies in Italy and Greece, to be conducted in connection with the new American School of Architecture in Rome, and under the direction of its secretary, six months of their time being spent in Rome itself. The single Fellowship thus created will be competed for this spring for the first time, the competition opening the 23d of March. The subject will be "A Building for a Savings Bank."

The subjects of the graduating theses in this department so far as announced will be a City Church, a Public Bathing Establishment, a Military School, a Surgical Hospital, a Gothic Church, a Casino, a Country Club, a Public Library, a Sanitarium, a Gymnasium, an Office Building.

The Biological Department.

Members of the Biological Department will make an extensive exhibit at the annual reception and exhibit of the New York Academy of Sciences. The exhibits will principally represent microscopal researches, the only exception being Dr. Dean's display of a series of artifically fertilized Gar Pike embryos from the Black River. The exhibits will be under two main heads. The first will cover the researches which have been going on in the laboratory during the last two years, upon the hereditary mechanism in animal cells in relation to the successive life phenomena. This begins with Professor E. B. Wilson's beautiful series of ova of the sea urchin, representing the process of fertilization, and embodying several of his recent discoveries. These are mainly that the spermatozoon contributes the *archoplasm* or dynamic element to the egg, together with the male *chromatin* or hereditary substance proper. The ovum, on the other hand, contains no dynamic material, but simply the hereditary material. The archoplasm is the factor of cell division and of the formation of all the tissues of the body. It is of the greatest interest, therefore, to find that this is contributed solely by the male in these animals. This discovery, which marks a turning-point in the science of the cell, has been paralleled by an independent discovery made by Dr. Morton Wheeler in the University of Chicago, that in certain forms the ovum contains the dynamic substance, while the spermatozoon has no trace of it. The induction which is made from these discoveries is that the chromatin or passive

hereditary material only is derived from both sexes, while the dynamic cell-dividing agent or archoplasm is perfectly neutral, so far as the sexes are concerned, and cannot be the bearer of peculiar hereditary qualities.

The exhibit of Mr. Gary N. Calkins shows the fertilization processes as an interchange of chromatin in several of the protozoa, and the exhibit of Mr. A. L. Kean shows the distribution of the chromatin in the developing cells of the lobster, which has been found to be a particularly favorable subject for study. The exhibit of the second class represents Dr. O.S. Strong's development of the nerve-staining methods discovered by Professor Golgi of Bologna, and by Professor Cajal of Cordova. The original method consists briefly in an infiltration of the nerve sheath with nitrite of silver. Mr. Strong has discovered two modifications of Golgi's process, which greatly simplify his method and require only two days' time instead of three weeks' time. Mr. Strong's latest discovery is in the combination of formalin with bichromate, which also gives beautiful and rapid results obtained by new methods in comparison with those by older methods.

Of the literary work in the Biological Department, the last number of the *Journal of Morphology* contains Mr. Strong's memoir upon "The Cranial Nerves of the Amphibia," of 128 pages in length, illustrated by four plates, one of which is a large folding lithographic plate in four colors. This is also presented as a thesis for the degree of Doctor of Philosophy. Under the direction of Professor Osborn, Mr. Strong has been engaged for five years in investigating the functional components of the cranial nerves of the amphibia, and this memoir marks the completion of this investigation and establishes a new philosophical basis for the understanding of the cranial nerves. The same number of the *Journal* contains a joint paper by Professor Wilson and Mr. Matthews, fellow in biology, upon "The Hereditary Substance in the Echinoderm Egg," mentioned above in connection with the Academy exhibit. This paper undermines the current belief as to the so-called quadrille of the centres established by Fol in 1891. Mr. Strong's memoir completes Volume I., Part I., of the *Studies from the Biological Laboratory*, which will soon be issued from the press of Ginn & Co., Boston. It is a volume of about 400 pages and forty plates.

New courses of lectures, beginning in the second semester, are those by Professor E. S. Wilson upon the Cell, embodying the latest progress in cytology, and by Mr. Gary N. Calkins upon the Protozoa, a course of thirteen lectures treating the protozoa historically and critically.

Professor Osborn's article in the *Ergebnisse der Anatomie und Entwickelungsgeschichte* (edited by Merkel and Bonnet, Gottingen), upon "Alte und neue Probleme der Phylogenese," has just been issued as a separate volume. Professor Osborn has been invited to become a permanent member of the editorial staff, which includes representatives from the following universities: Dorpat, Giessen, Breslau, Rostock, Halle, Kiel, Tübingen, Vienna, Göttingen, New York, Konigsberg, Munich. This article is also the basis of an address opening the discussion of the American Society of Naturalists, upon the "Relations between Variation and Environment," at the recent Baltimore meeting. In the American Museum of Natural History Prof. Osborn has been engaged during the past autumn in securing subscriptions for the famous collection of North American Fossil Mammals, made by Prof. E. D. Cope, of the University of Pennsylvania. This collection is very

largely the basis of the whole modern science of mammalian palæontology, and forms the subject of Prof. Cope's great memoirs published by the government. It includes 550 type specimens and a number of the most famous fossils in the world, such as the skeleton of the small four-toed horse, and of Phenacodus. The contract was signed about three weeks ago, and the entire collection is now safely stored in the museum. It will be exhibited in the large hall on the third floor of the east wing, which will be entirely devoted to the collections from the west, made or purchased by the museum since Prof. Osborn was appointed curator three years ago.

THE METALLURGICAL DEPARTMENT.

An optional class of third and fourth year students, under the instruction of Mr. Struthers, has been started in practical work in pyrometry.

This work consists of measuring high and low temperatures by means of the various pyrometers of the department.

An American gas-furnace gives steady temperatures up to 1450° C. The pyrometers available are Chatelier's thermo-electric, Chatelier and Cornu's photometric, Mesuré and Nouel's optical pyrometer, Siemen's water pyrometer, Seger's pyramids and Hobson's hot-blast pyrometer.

These pyrometers will be used in the practice work of measuring flame and furnace temperatures and the results compared to ascertain their respective degrees of accuracy.

A trip has been arranged for the fourth class students to visit the works of the Nichols Chemical Company at Laurel Hill, L. I. The class will be under the charge of Mr. Struthers.

The new Herreshoff water-jacket furnace, the Bessemer converter for copper matte and the copper refining furnaces will be studied. Other trips to lead and steel works in the vicinity are being arranged.

The Russell Process Company have presented to the department their exhibit at the World's Fair at Chicago. It consists of a complete model of a lixiviation plant, made to scale, a suite of samples and sixteen framed photographs.

The department has also received the following additions to its collections:

A number of titanium slags made by A. Rossi. Full description given in his paper in the *Transactions* of the American Institute of Mining Engineers.

Fifteen specimens of various cast irons and spiegeleisen, from J. F. Kemp.

One specimen of nitro-cyanide of titanium, from E. L. Kurtz.

Two honeycombed steel ingot specimens, from E. L. Kurtz.

Eleven specimens of manganese steel, being part of the World's Fair Columbian Exposition, presented by R. A. Hadfield.

Four specimens of shattered armor plate from the Sandy Hook proving grounds, by E. L. Darling; iron fragments from rail saw, by C. F. Chandler.

One Brazilian batea, from G. O. Gordon.

One zinc oxide deposited in retort, by New Jersey Zinc Company.

Eight specimens of carborundum, Prof. C. F. Chandler.

One specimen of cupola slag.

One specimen of copper slag, containing very fine crystals of melilite,

the top edge of prism being nearly an inch in length. This noteworthy specimen was presented by A. C. Lane, of Dollar Bay, Mich., through the courtesy of Prof. J. F. Kemp.

THE MINERALOGICAL DEPARTMENT.

The new course in Optical Mineralogy, in charge of Dr. Luquer, begins with the commencement of the second term of this year. The course is designed as introductory to petrography, and includes a view of the principles of optics relating to polarized light, the application of these principles in the different pieces of apparatus and in petrography; a description of the petrographical microscope; the optical character of the common rock-forming minerals and the most convenient methods of recognizing these minerals in rock sections. The work will consist mainly in the critical study of 170 sections carefully selected to illustrate the appearance of minerals in rock sections. In addition there are two very complete sets of sections of crystals of the rock-forming ing minerals.

Among the additions to the mineral collection are a large crystal of monazite from South Lyme, Conn., probably the largest ever found in this country; a large rhombic dodecahedron of cuprite from the Anaconda mine, Montana; a nickel alumina silicate from North Carolina, crystals of hematite from Zacatecas, white pyroxenes from Port Henry, N. Y., and three enormous allanites obtained by Prof. Kemp from Mineville, N. Y.

Mr. Ries has constructed a useful piece of apparatus which simplifies the cutting of properly oriented sections for measuring the optic axes. It consists of a simple steel frame in which the crystal to be sectioned is fastened at the proper angle by means of plaster of paris. By this means sections giving accurate results are always obtained.

A more satisfactory dark room with electric light has been provided for goniometrical work.

The card catalogue of mineralogical literature now exceeds ten thousand cards and will reach twenty thousand.

The publications of the past year by officers of the department have been:

BY PROF. MOSES.—Elements of Mineralogy, Crystallography and Blowpipe Analysis. 342 pages, 336 illustrations. D. Van Nostrand Company. New York: Price $2.

Simplified Methods for Obtaining Axial Cross of any Crystal from any Projection of the Isometric Axes.—SCHOOL OF MINES QUARTERLY, XV., pp. 214–218.

Index to Mineralogical Literature.—SCHOOL OF MINES QUARTERLY, XV., 163–179.

BY DR. LUQUER.—Optical Recognition and Economic Importance of the Common Minerals found in Building Stones.—SCHOOL OF MINES QUARTERLY, XV., pp. 285–336.

Report on the Mineral Exhibit of New York State at the World's Fair. Report of commissioners, Albany.

Relative Effects of Frost and the Sulphate of Soda Efflorescene Test in Building Stones.—*Transactions Am. Soc. Civil Engineers.*

BY H. RIES.—On Some New Forms of Wollastonite from New York State.—*Trans. N. Y. Acad. Sci.*, Vol. XIII.

Additional Notes on Wollastonite from New York.—*Trans. N. Y. Acad. Sci.*, Vol. XIII.

Micro-Organisms in the Clays of New York State.—*Trans. N. Y. Acad. Sci.*, Vol. XIII.

Note on Occurrence of Cretaceous Clay at Northport, L. I.—SCHOOL OF MINES QUART., July, 1894.

Artificial Crystals of Zinc Oxide.—*Amer. Jour. Sci.*, September, 1894.

Report on Clays, Glass-Sands and Road Metals.—*Report of N. Y. World's Fair Commissioners.*

Brick and Pottery Clays of N. Y. State.—*Bull. N. Y. State Museum*, No. XII. (In press).

DEPARTMENT OF MECHANICAL ENGINEERING.

The assignment of subjects among the officers of the department this year is essentially the same as was provided at its first organization a year ago. Prof. Hutton takes the subjects of The Applications of Heat to Motive Power in the generation of steam and the production of tension in air and other vapors. This course covers the questions of Smoke Prevention, Natural and Mechanical Draft, Boiler Heating Surface, Multiple Expansion of Steam, Air Compression, and the Theories of Processes of Refrigeration. A second course covers the theory and applications of the other Motor Forces, and embraces Water Motors, Hydraulic Engines and Wheels and Wind and the less usual sources of power. Into this course also is incorporated a great deal of that which belongs to Dynamics, both in the proportion of parts and the tests of efficiency of motors and machines.

The third course with the Senior class, is the course which will be remembered by most of the graduates of the School on Engines and Boilers, the only change being due to a greatly increased use of the projection lantern in a room which is not darkened.

The course for the Junior class, or third year, has been considerably extended in the direction of practice by adding considerably to the amount of work in the laboratory. Besides the standard tests in tension, compression, and transverse resistance, other and special experiments are being added as rapidly as possible. It is desirable to increase the laboratory equipment as far and as fast as possible, and the co-operation of the graduates will be very fully and earnestly appreciated along this line.

A change goes into effect this winter which should be followed by good results, in that the course of instruction in Steam Engines is to be begun in the second term of third year, and to run forward into the fourth. This will bring the general treatment of steam motors to precede the special discussions in electrical engineering and mining, which has been felt very desirable of late.

For the Senior or fourth year class, the work on the Locomotive Engine and with the machinery for the transmission of power, the principal dependence is upon Mr. Woolson, who also carries a considerable burden in the department of testing, which he is making his specialty. Mr. Mayer has as his assistant this fall, Mr. T. H. Harrington of 1889, and Mr. L. E. Gregory of 1893, assists in the testing department.

The organization on the present basis seems to be working very satisfactorily and well.

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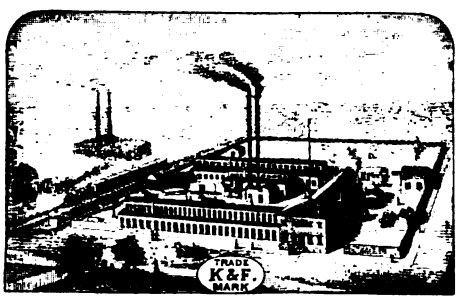

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SCHOOL OF MINES QUARTERLY.

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MODERN CALORIMETERS AND THEIR USE.

BY JOSEPH STRUTHERS, PH.D.

THE object of calorimetry is to measure the quantity of heat which a body parts with or absorbs when its temperature sinks or rises through a certain number of degrees, or when it changes its condition. Quantities of heat may be expressed by any of its directly measurable effects. The most convenient is the alteration of temperature, and quantities of heat are usually defined by stating the extent to which they are capable of raising the temperature of a known weight of a known substance, such as water.

The *unit* of comparison called a *thermal unit*, is not everywhere the same, the varying factors being the weight of water taken and the range of temperature through which the water is raised.

As for the different weights of water taken the expression of the results is the same in all cases, because the weight of substance experimented on always corresponds to the weight of water taken as the unit; thus, if a kilogramme of substance be taken to ascertain its calorific value, the unit selected for expressing that value will be a kilogramme of water, or if a pound of substance be taken the unit selected will be a pound of water, etc.

When the range of temperature is considered the results differ. The two different standards of temperature are the degree Fahrenheit and the degree Centigrade, and depending upon which is selected, so will the resultant numerical expression of the calorific

value be greater or less, and will be in the ratio of the values of the Fahrenheit degree as compared to the Centigrade degree, that is, as nine is to five.

The unit of temperature taken to conform to the metric system is the degree Centigrade, and is called the *calorie*. The unit of temperature taken in England is the degree Fahrenheit, and is called the *British Heat Unit* or *British Thermal Unit*, the abbreviation being *B. H. U.*, or *B. T. U.*

Thus we find the expression for the calorific value of carbon to be 14,544 in the case of the British heat unit, and 8080 in the case of the calorie. These two values are in the ratio of the values of the Fahrenheit degree and the Centigrade degree.

The calorific value of a fuel is the number of heat units developed by the complete combustion of a given weight of the fuel, and is expressed in heat units differing in value, depending on the unit used, whether the calorie or the British thermal unit.

The determination of the calorific value of fuel is an important subject, and one which has not received the attention it deserves.

The methods of ascertaining calorific values of fuels may be grouped as follows:

I.—By calculation from the chemical composition.

II.—By combustion on a small scale in a calorimeter.

III.—By combustion on a large scale under a well arranged steam boiler used as a test boiler.

Since the last method is boiler practice and does not deal with calorimeters, a few words will suffice for its discussion here.

The importance of testing fuels in large amounts under boilers is obvious, as the results obtained either by calculation or by a calorimeter treating a few grammes of combustible can only be regarded as relative.

To ascertain the relation between these two methods of testing fuels is of importance. Much depends upon the boiler, although combustion under it can seldom be as perfect as in a calorimeter; the rate of combustion and other conditions also affect the results.

Donkin and Holliday* tested a number of coals and gas coke, using for comparison a Thompson calorimeter and a Lancashire boiler. Their experiments showed an average of 35 to 40 per cent. difference in testing values in favor of the calorimeters.

* Donkin and Holliday, *Proceedings of the Institute of Civil Engineers*, Vol. CII., Session 1889–90, Part IV.

This approximate value having been obtained for given conditions, and the calorific value of the coal being known, it is easy to calculate what may be expected in practice.

In Germany, and in other places on the Continent, a few testing stations have been erected to treat fuel on a large scale. One of these is at Munich, and includes in its outfit calorimeters, apparatus for fuel and gas analysis, and a tubular test-boiler. It is not within the scope of this article to discuss this method of estimating the heating value of fuels. For those interested, a description of a plant of this type will be found in the *Minutes of Proceedings Inst. C. E.*, Vol. LXXIII., p. 328.

I.—To calculate the heating value of a fuel requires a reliable chemical analysis, and this is necessarily expensive. Moreover, when the analysis is obtained, the leading authorities are not yet quite agreed upon the value to be assigned to the various combustible elements, nor upon the allowance to be made for possible changes of state, during combustion, from solid to liquid, or from liquid to gaseous. Nor are they agreed concerning the chemical combinations which exist previous to combustion, and their effect on the results; whether, for instance, when hydrogen and oxygen are both present, they are necessarily already combined as water, or combine during combustion.

The following are the calorific values of the elements generally found in all fuels:

	British heat units.
Carbon,	14.544
Hydrogen,	62.032
Sulphur,	4.032

Assuming that the behavior of carbon, hydrogen, etc., in combination, is the same as that of carbon alone, the calorific value of a sample of coal of which the composition has been determined, can be calculated as follows:*

	Per cent.		Calorific value of element.		Heat per unit weight of coal.
Carbon,	0.880	×	14.544†	=	12.799
Hydrogen,	0.045	×	62.032†	=	2.791
Sulphur,	0.008	×	4.032†	=	32
Oxygen, nitrogen, and ash,	0.067	×	.....	=	.....
Totals,	1.000				15.622*

* *Op. cit.*

† British Heat Units.

The calorific value of carbon, in the condition of amorphous carbon, graphite and diamond, has been determined by Berthelot and Petit, the results being:

	British heat units.
Amorphous carbon,	14.647
Graphite,	14.219
Diamond,	14.146

The results obtained for amorphous carbon is practically the same as that of Favre and Silbermann, namely, 14.544. M. Cornût assigns a higher value than this to the volatile portion, taking 20.185 thermal units, and retains the value 14.544 for the fixed portion of the carbon. He thus values a coal rich in hydrocarbon much higher than anthracite.

Dulong's method of calculating the heating power of a coal from its analysis is to assume that all the oxygen present in the coal is combined with hydrogen, and only the excess of hydrogen over that necessary to satisfy the oxygen is available for heat-production.

In the analysis of the coal given above, the available hydrogen will be:

$$0.045 - \frac{0.032}{8} = 0.041,$$

and the thermal units derived from the hydrogen will be reduced from 2.791 to 2.343.

Mr. Ser gives the following formula for calorific values of any coal:

$$5.184\left(\frac{\text{carbon}}{3} + 8\ \text{hydrogen}\right).$$

The result will be the values in British heat units. Mr. Scheurer-Kestner has compared these methods, with the following results:*

	French calories.	British thermal units.
Dulong's formula,	8.452	15.214
Scheurer-Kestner's formula,	8.586	15.455
Cornût's formula,	8.674	15 613
Ser's formula,	9.268	16.682
Experimental result,	8.864	15.955

* *Bulletin de la Société de Mulhouse* (1888), Vol. LVIII., p. 324.

In this instance, Cornût's method gives the nearest result to practice, but this is not always the case. Authorities give the calorific values as of pure coal; that is, the results obtained in any experiment are corrected for the amount of incombustible matter present, and the figures given represent what the result would be if the sample were all combustible.* The *pure* coal is calculated by deducting the amount of moisture and of ash present in the sample.

It is necessary to correct the calorimetric determination of the value of a given coal for the latent heat of vaporization of water. This aqueous vapor is condensed in the calorimeter and the latent heat becomes sensible and is so recorded, while in boiler practice, no possible arrangement could be devised to economically extract this latent heat. If this correction be applied to the example given above it will be found that the hydrogen produces 0.4 unit weight of water and with 966 as the latent heat of vaporization the difference, 391.2 thermal units, is the quantity by which the calculation should be reduced. The same result may be obtained directly by taking the calorific value of hydrogen at 52.357 instead of 62.032.

The determination of the amount of heat developed by chemical combustion has been accomplished by apparatus especially devised for the purpose. The apparatus so devised, however, could not be used for determining the calorific value of coals except in the hands of skilled experts.

Messrs. Favre and Silberman, between 1845 and 1852, made various determinations, which have since become classic, of the calorific values of different substances. The apparatus they used is so well known and has been so often described,† that it is sufficient to say that the substance was burned in a copper vessel, in a stream of oxygen gas, the products of combustion passing out through a coil around which water circulated, and from the rise in temperature of the water, the calorific value was determined.

Elaborate precautions were taken to minimize losses by radiation, and the gases of combustion were sometimes analyzed to study the results. The correctness of the calorific value of amorphous carbon obtained by Favre and Silbermann has lately been verified by the experiments of Messrs. Berthelot and Petit, with

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* *Bulletin de la Societe de Mulhouse* (1888), Vol. LVIII., p. 324.

† Ganot's *Physics*. Translated by E. Atkinson. Tenth edition, p. 401.

the bomb calorimeter, a description of which is given at the conclusion of the article.

From among the number of calorimeters which have been used by various investigators, the following list has been compiled with a brief description of each :

Rumford's calorimeter, 1814. It consisted of a vessel containing a known weight of water placed above a small chamber in which the sample of fuel was burned. The products of combustion were collected in a hood and passed through a coiled pipe placed in the water. The rise in temperature of the water was measured by a thermometer.

Dr. Ure's calorimeter was an improvement on Rumford's design, using larger quantities of fuel and water. The apparatus consisted of a large copper vessel of 100 gallons capacity, communicating with the top of a small furnace in which the sample of coal was burned. Air was supplied by a bellows and circulated twice around the furnace before reaching the fuel. Ignition was effected by the addition of half an ounce of glowing charcoal and the heat developed was said to be completely absorbed by the water. In this instrument combustion could scarcely been perfect owing to the small size of the combustion chamber. An analysis would probably have disclosed the presence of carbonic oxide on the gases of combustion, and of unburned carbon in the ashes.

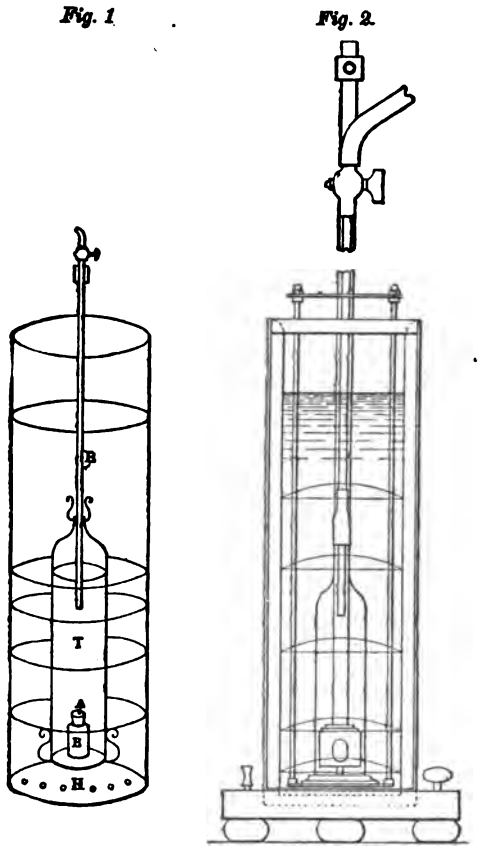
Favre and Silbermann's calorimeter has already been briefly described.

Of the modern calorimeters, Thompson's is in general use in England and while not possessing the accuracy of the Mahler bomb calorimeter, its low cost and ease of manipulation justifies its use. A detailed description is given below.

The Thompson calorimeter.—This calorimeter consists essentially of two glass cylinders the smaller of 2000 c.c. capacity and placed in the larger cylinder, the lip around the edge of the inner cylinder serving to support it by resting on the top of the outer cylinder. The annular space between these cylinders serves to prevent any great changes of temperature by the heat absorbed from the atmosphere. An inverted bell-glass is placed beneath the water contained in the inner cylinder by which means the gaseous products from the combustion of the fuel to be tested are compelled to flow or bubble through the 2000 c.c. of water, imparting to the water their specific heat. This bell-glass is of sufficient size so as

not to impede combustion and is placed on a perforated grating or ring which allows for passage of the products of combustion. Firmly fastened to this plate is a brass cup, also perforated, which serves as a support for the crucible.

Around the outside of the inverted bell are a series of wire-



Thompson's Calorimeter for Testing Fuels.

gauze rings which are intended to cause the water to circulate and thus compel uniform diffusion of the bubbles of gas through the water.

The platinum cup or crucible which is supported on the elevated cup attached to the bottom plate is fixed so that its upper level is above the level of the water in the inverted bell-jar. This crucible

serves as the combustion chamber for the fuel and is enclosed in a fire-clay crucible.

The oxygen to support the combustion of the fuel is supplied to the interior of the bell-glass by a tube through which a stirrer-rod is moved by a milled cap at the top. The rod is attached to the top of the tube by an elastic connection, and is employed to stir the fuel during combustion. The oxygen is supplied from a holder, which may be of iron or steel, containing the oxygen under very high pressure, or an ordinary metal tank having the oxygen under low pressure, and displaced by water. Regulating valves control the supply of oxygen to the crucible.

The method of operating this calorimeter is as follows: The inner cylinder is filled to the graduated mark requiring 2000 c.c. of water; this is then placed in the outer cylinder, which contains sufficient water to fill the annular space between the cylinders, thus water-jacketing the inner cylinder. A given weight, say 5 grammes of finely pulverized and dry coal, is put in the platinum crucible, which is placed within the fire-clay crucible supported on the centre of the stand attached to the base of the inverted bell-glass. The coal is ignited by a strand of lamp-wicking used as a fuse and dropped into the crucible. The oxygen gas is supplied gently, and the inverted bell-glass with its crucible is lowered into the water in the glass vessel.

The combustion will be violently active and the gaseous products bubbling through the water, will impart their sensible heat thereto.

In some styles of this calorimeter there is a small glass tube fixed at right angles to the tube leading into the top of the bell-glass; to this is attached a piece of rubber tubing closed with a spring clip.

After the fuel has been consumed, if this spring be released, it will permit the water to enter into the inverted bell, so that the whole of the apparatus and water is raised to a uniform temperature. The bell-glass can now be lifted up and down several times, the annular gauze rings thoroughly agitating the water and equalizing the temperature.

In order to ascertain the specific value in equivalents of water of the internal apparatus of the calorimeter, the following method is adopted:*

* *Journal of the Iron and Steel Institute*, No. 1, 1892, p. 188.

Two thousand c.c. of water at 15° C. above the temperature of the atmosphere is poured into the calorimeter, which has the bell-glass, stand and crucible, all in place. Its temperature is the temperature of the laboratory.

The water is thoroughly agitated by raising and lowering the bell-glass, and is finally allowed to flow into the inverted bell-glass. The procedure corresponds both in time and manipulation to that followed in an actual test and the lowering of the temperature of the water will represent the degree of heat that will have to be allowed for in the determination of calorific value. In ascertaining the amount of water to which the apparatus is equivalent, it is assumed that one-half of the difference between the temperature of the 2000 grammes of water and that of the air is equivalent to 2000 grammes of water, the result is calculated on this basis. For instance, if the atmospheric temperature in the dry calorimeter is 30° and the water poured into the calorimeter is 35°, then, after the heat is absorbed by the apparatus from this water, it reduces the temperature to 34.5°, the equivalent of water would thus be measured

$$\frac{2000(35-34.5)}{\frac{35-30}{2}} = 400$$

This number of grammes must be added to the weight of water used in the calorimetric estimation. The temperature of the water taken before and after the combustion of the fuel in the calorimeter will give the data for calculating the value of the fuel. Thus arise of 4° C. in a sample weighing 4 grammes would give

$$\frac{4 \times 2400}{4} = 2400$$

the thermic value of the fuel in calories.

This calorimeter enables determinations of sufficient accuracy for comparison to be performed in some ten minutes from the time the fuel is dried. In drying and pulverizing the fuel, care must be taken to avoid too high a heat, as otherwise some of the hydrocarbons might be volatilized.

When liquid fuels are to be tested, asbestos or pumice-stone is dipped in the oil, having been previously weighed; the weight

after dipping and after being placed in the calorimeter would give the weight of the oil absorbed and burned. The oil so heated will burn in the crucible like a torch.

The essential conditions for the correct determination of heat of combustion are, that the combustion should be complete, that the heat should pass into the water of the calorimeter, and that the combustion should be as rapid as possible.

The calorimeter devised by Berthelot* answered these requirements. The combustion takes place in a bomb or closed steel vessel filled with oxygen under 20 to 25 atmospheres pressure, and almost completely immersed in the water of the calorimeter. Under these circumstances a hydrocarbon will burn completely to carbon dioxide and water in a few seconds, the products of combustion cannot escape, and the heat passes into the surrounding water in the course of two or three minutes.

Berthelot's calorimeter, while giving accurate results, is too costly for common use, the platinum lining to the shell raising the cost to $1500. Berthelot's original calorimeter† has been modified from time to time by various experimenters, notably Stohlmann, Kleber, and Langbein.‡

The most important modification, however, was made by M. Mahler, in which the expensive platinum lining of the bomb was replaced by a thin coating of enamel without impairing the efficiency of the apparatus, and lowering its cost so as to permit of general use.

Mahler's modified calorimeter has been frequently described in the scientific journals § and its importance warrants a full description here.

The bomb, with its auxiliary apparatus, is clearly shown in the illustration.

The apparatus, as constructed by M. Golaz, of Paris, consists essentially of a shell of forged Siemens-Martin steel, B, of 564 cubic centimeters capacity, 15 centimeters high and 10 centimeters diameter. Its thickness is 8 millimeters and weighs about 4 kilo-

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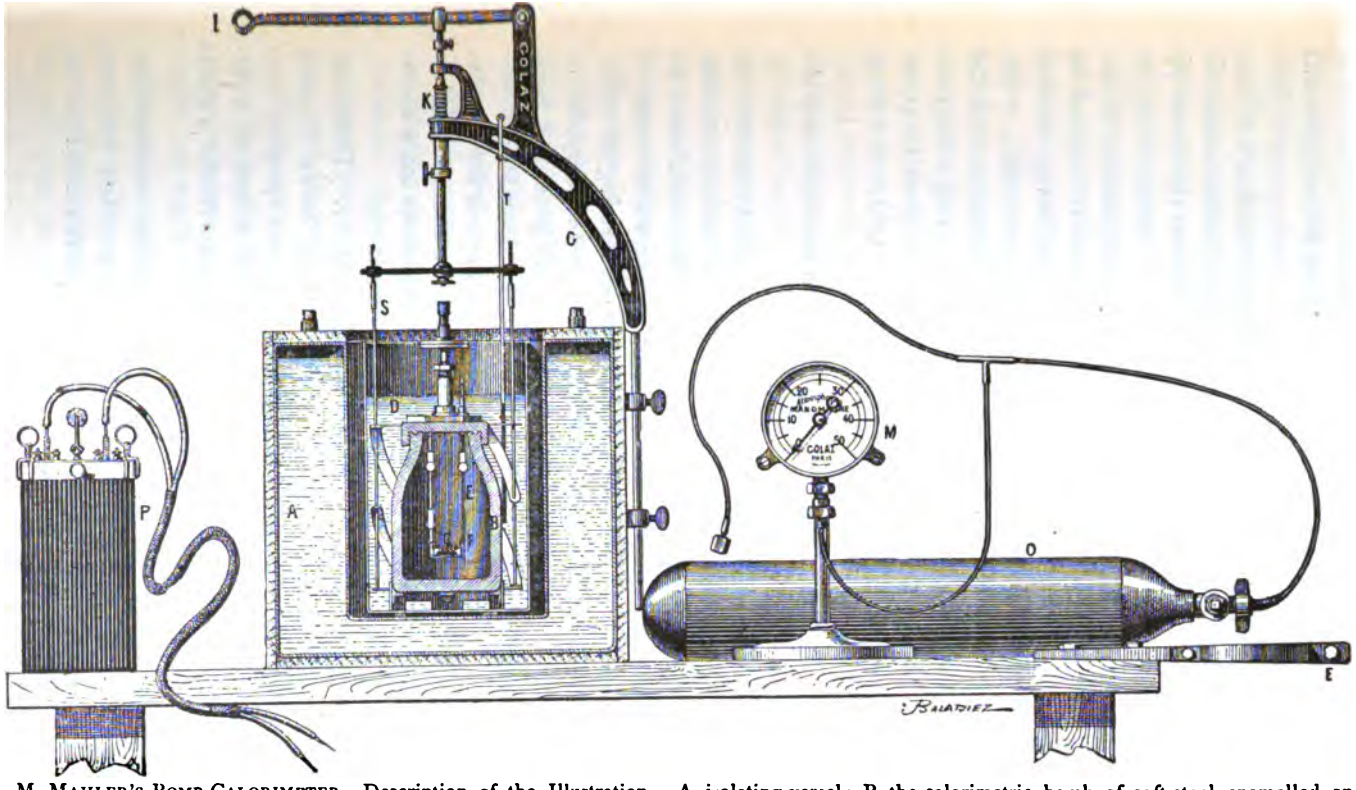
* *Annales des Physiques et de Chemie*, 1881 and 1885.

† *Comptes Rendus*, 91, 188.

‡ *Journ für prakt. Chemie*, 1889, Vol. XXXIX., p. 503.

§ *Génie Civil*, January 23, 1892. *Bulletin de la Society d'Encouragement pour l'Industrie Nationale*, June, 1892. *Journal of the Iron and Steel Institute*, No. 1, 1892. *Mineral Industry*, Vol. I., 1893.



M. MAHLER'S BOMB CALORIMETER—Description of the Illustration.—A, isolating vessel; B, the calorimetric bomb of soft steel, enamelled on the inside surface; C, the platinum dish to hold the combustible; D, the calorimeter vessel filled with water; E, the isolated electrode; F, the iron wire which ignited the combustible; G, the support for the agitating apparatus; K, the agitating mechanism; L, the arm for imparting power to the mechanism; S, the agitator; M, is the manometer; O, the cylinder of oxygen under high pressure; P, the chromate battery for heating the iron wire in the bomb; T, the thermometer; E′, the clamp for holding the bomb while the cover is screwed on or removed.

grammes. The inside of this shell or bomb is covered with a thin film of white enamel to prevent corrosion by the oxygen and the acids which are among the products of combustion. This coating is very thin, and offers no appreciable resistance to the transmission of heat. A platinum tray, C, of 28 millimeters diameter and 5 millimeters in depth is suspended from the cover by a platinum rod of 1½ millimeters diameter. A similar rod, insulated from and passing through the cover, reaches nearly to the tray and serves as the other electrode. The cover is secured to the bomb by screw and threads, a hermetical joint being insured by a ring of lead fitting into a groove cut in the top surface of the bomb. This lead ring is 1½ millimeters in thickness, and the groove is less in depth than the thickness of this ring; the projecting part, being soft, yields a perfectly gas-tight joint by pressure. The oxygen is passed through a needle valve in the stem of the cover.

The bomb rests on a ring support, flanged on the inside to hold it in proper position.

The calorimeter vessel is a thin brass pail 23 centimeters in height and 15 centimeters in diameter. A wire handle, attached to the upper rim, admits of ease in handling. This vessel rests on a wooden support, and is placed in a large double-walled vessel of 18 centimeters inside diameter, the hollow walls forming an annular space 6 centimeters wide, containing water at the temperature of the room. This insulating vessel is properly protected from thermal changes from the atmosphere by a covering of felt 1 centimeter thick. The mechanical stirring device shown in the illustration insures a thermal equilibrium of the water in the calorimeter.

This protecting vessel is so efficient that the water often varies less than the hundredth of a degree in fifteen minutes.

The thermometers used are of extreme delicacy. Three are used: one reading from 7° to 28° C., one from 14° to 24° C., and the third from 17° to 29° C. Each degree covers a space of 3 to 3½ millimeters, and the graduations read to the fiftieth of a degree. Hundredths of a degree, or even finer, can be read if a glass be used for reading.

Method of Manipulation.—One gramme of the combustible, whose calorific power is to be determined, is weighed into the platinum tray, which is then attached to the platinum rod of the calorimeter cover.

A known weight of fine iron wire is stretched from the insulated rod to the rod supporting the tray and buried in the combustible.

The top is then tightly screwed on by means of a heavy wrench, the bomb being firmly held in a special lead-lined clamp. The needle valve is then opened, and the stem of the calorimeter connected to the oxygen supply by a slender copper tube.

The cylinder valve is cautiously opened, and the oxygen flows into the bomb until a pressure of twenty to twenty-five atmospheres is shown by the manometer gauge attached to the supply tube. The needle valve is then closed, and the bomb immersed in the calorimeter, the water therein contained covering the bomb nearly to the top of the insulated electrode. In the apparatus in use in the metallurgical laboratory of the School of Mines 2512 grammes of water were usually taken, as this amount plus the water value of the calorimeter (488 grammes), gives a convenient factor of calculation. The temperature of the water should be two or three degrees lower than the temperature of the room and of the water in the surrounding jacket. Before igniting the combustible in the bomb, the temperature of the water in the calorimeter is noted from minute to minute until it becomes fixed, the water being thoroughly agitated by means of the mechanical stirrer. This time is usually four or five minutes.

The time is accurately and conveniently recorded by means of a stop watch, with the milled head attachment for causing the minute and second hands to return to zero immediately without interrupting its action.

The temperature now being constant, the combustible is ignited by passing an electric current through the iron wire, heating it to redness. A bichromate plunge battery is generally used for this purpose, one wire from the cells being connected to the insulated rod, and the other touched to the exposed surface of the bomb.

In ten seconds the temperature is observed to rapidly rise, and then more slowly until the maximum is reached, usually in two or three minutes, after which the temperature gradually falls. Readings are made at minute intervals for four or five minutes in order to determine the consequent correction to be made for the cooling of the calorimeter by radiation. The bomb is then removed from the calorimeter and the needle valve cautiously opened to allow the escape of the products of combustion and the remain-

ing oxygen. When no more gas flows out, the top is unscrewed, and the interior of the bomb carefully washed with distilled water to collect the liquid nitric acid formed during the combustion. The amount of acid is volumetrically determined by titration with standard alkali. If the fuel contains sulphur, it is determined in the solution. The data being thus obtained, the calculation is as follows:

The weight of the water taken, plus the water equivalent of the apparatus, multiplied by the corrected rise in temperature, gives the heat of combustion of the substance.

This particular case is quoted from Mahler:*

Let Q, be the calorific power of the combustible;

D, the difference of temperature observed;

a, the correction for cooling;

P, the weight of water in the calorimeter;

P^1, the water equivalent of bomb and accessories;

p, the weight of nitric acid;

p^1, the weight of iron wire;

0.23 cal. is the heat of formation of nitric acid, and 1.6 cal. is the heat of combustion of one gramme of iron.

We have

$$Q = (D + a)(P + P^1) - (0.23\,p + 1.6\,p^1).$$

The following shows the figures obtained in a determination of the heating power of a sample of Nixon's navigation coal from South Wales. The analysis was

Fixed carbon, without ash,	86.30
Volatile matter, without water,	10.15
Hygroscopic water,	1.85
Ash, by calculation,	1.70
	100.00

Preliminary Period.		Combustion.		After Combustion.	
0 minutes,	15.20°	3½ minutes,	16.60°	7 minutes,	18.32°
1 "	15.20°	4 "	17.92°	8 "	18.30°
2 "	15.20°	5 "	18.32°	9 "	18.30°
3 "	15.20°	6 "	18.34°	10 "	18.30°
			Maximum,	11 "	18.26°

25 atmospheres pressure.

* *Bulletin de la Société d'Encouragement pour l'Industrie Naturalle*, June, 1892.

$$a = \frac{18.34° - 18.26°}{5} = 0.016° \text{ per minute.}$$

Difference of temperature observed, ...	3.140°
Correction 4 — 5, 5 — 6, 0.016 × 2 = ...	0.032°
Correction 4 — 3½, ...	0.005°
Total, ...	3.177

For ease in calculation this result, 3.177, is taken as 3.18.

Then, for the heat disengaged we have (2200 + 481) grammes × 3.18° = 8.5256 calories. Weight of iron wire 0.025 × 1.6 = 0.040 calories. Nitric acid formed 0.15 × 0.23 = 0.0345. Total 8.4511, or for one kilogramme of the coal 8.451 calories.

Different experiments with the same coal gave the following results:

	1st.	2d.	3d.
Flaming coal from Montvic, . . .	7.790	7.806	7.816
Gas coal from Commentry, . . .	7.870	7.868	7.868
Gas coal from Montrambert, . . .	8.268	8.243	8.282

Corrections.—1. Correction for the influence of the temperature of the environment.

2. Correction for the formation of nitric acid.

3. Correction for the combustion of the iron wire.

4. Correction for the formation of sulphuric acid.

As the period of combustion is so short, M. Mahler has given a method of correction based on Newton's law which gives results sufficiently exact for technical work. These rules are as follows:*

1. The law of decrease of temperature observed after the maximum represents the loss of heat before the maximum, and for any given minute, on condition that the mean temperature of this minute does not differ more than 1 degree from the maximum temperature.

2. If the temperature of the given minute differs by more than one degree but less than two degrees from the maximum, the number that represents the law of decrease at the moment of the maximum, less 0.005 will give the desired correction.

The Regnault-Pfaundler formula for the correction due to the temperature of the environment is more complex.

If the preliminary period and the final period are each five min-

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Op. cit.

utes with readings of the thermometer every minute, the correction according to this formula would be:*

$$[t_6 + t_7 + \ldots . t_{n-1} + \frac{t_5 + t_n}{2} - (N - 5)t_m] \frac{D - d}{T - t_m} + (N - 5)d$$

when t indicates the temperature at the end of the minute designated by the subscript; t_5 is the instant of firing; N is the number of the maximum reading; t_m is the average of the five readings before firing; T is the average of the readings of the final period; D is the average change in temperature during the final period, and d is the average change in temperature during the preliminary period.

In practice the maximum temperature nearly always occurs on the seventh, eighth or ninth moment. The formula can be reduced for these three cases to the following forms which are easy to calculate.

When the maximum is the end of the seventh moment the correction for the loss or gain of heat during the minutes 5–6 and 6–7 is:

$$\frac{1}{6}\left\{\frac{[(2t_6 + t_7) - (2t_0 + t_5)]\,[(t_7 + t_5) - (t_0 + t_{12})]}{(t_{12} + t_7) - (t_0 + t_5)} + 2(t_0 - t_5)\right.$$

When the maximum is the eighth moment the loss or gain for the minutes 5–6, 6–7 and 7–8 is:

$$\frac{1}{6}\left\{\frac{[(2t_6 + t_7 + t_8) - (3t_0 + t_5)]\,[(t_8 + t_5) - (t_0 + t_{13})]}{(t_{13} + t_8) - (t_0 + t_5)} + 3(t_0 - t_5)\right.$$

When the maximum is the ninth minute the loss or gain for the minutes 5–6, 6–7, 7–8 and 8–9 is:

$$\frac{1}{6}\left\{\frac{[(2t_6 + t_7 + t_8 + t_9) - (4t_0 + t_5)]\,[(t_9 + t_5) - (t_0 + t_{14})]}{(t_{14} + t_9) - (t_0 + t_5)} + 4(t_0 + t_5)\right.$$

This correction becomes a minimum when the temperature before firing is rising about three times as fast as it falls after the maximum.

* Ostwald: *Lehrbuch des Allegemeine Chemie.*, 2d Ed., Vol. I., p. 572.

E. E. Slosson and L. C. Colburn* compared these two methods in some twenty cases. Their results showed a difference of 0.0013 which on 1 gramme naphthalene would amount to about three calories or .03 of 1 per cent., a difference within the limit of error in technical work.

2. *Correction for Formation of Nitric Acid.*—About fifty milligrammes of nitric acid are formed from the nitrogen of the air by the combustion, and it is necessary to ascertain the amount produced and subtract the heat of formation from the heat of combustion of the substance under examination. The heat of formation of nitric acid is 227 calories per gramme.

The amount produced is estimated by titration with a standard alkali solution containing 3.706 grammes of sodium carbonate, Na_2CO_3, per litre.

One cubic centimeter of this solution is equal to .0044 gramme of nitric acid, the heat of formation being $.0044 \times 227 = .9988$ calories, or in technical work, one calorie, so that the number of cubic centimeters required to titrate the washings of the bomb can be written at once as calories. Methyl orange is used as an indicator.

3. *Correction for the Combustion of the Iron Wire.*—The combustion of the iron wire used to ignite the fuel has to be taken into account, and correction made by taking a known weight of wire and subtracting its heat of combustion. A No. 32 to 36 Brown and Sharpe gauge is suitable, and it is preferable to use the copper-plated wire, as the plain wire becomes oxidized on the surface.

A metre of No. 36 wire weighs 0.3160 grammes, the amount used in the experiment is 4.8 centimeters = 0.15168 grammes, which, multiplied by the heat of combustion of iron under these circumstances, 1650 calories per gramme,† yields a combustion heat of 25 calories.

This is on the assumption that all the iron is burned to Fe_3O_4. Analyses of iron oxide produced by some twenty combustions,‡ showed much variation in the amount of iron in the state of Fe_3O_4. The character of the oxides formed is variable, and the ordinary correction is consequently inaccurate by several calories.

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* "The Heating Power of Wyoming Coal and Oil."—*Special Bulletin* of the University of Wyoming, January, 1895.

† Berthelot, *Traite Practique de Calorimetrie Chemique*, page 139.

‡ Slosson and Colburn, *Op. cit.*, page 28.

4 *Correction for the Formation of Sulphuric Acid.*—The presence of sulphur in the combustible necessitates another correction, for the free sulphuric acid formed by the combustion of sulphur compounds will be titrated as nitric acid, although its combustion heat is different and the heat of the sulphur is a legitimate part of the heat of combustion of the fuel. The sulphuric acid must, therefore, be determined in the solution after the titration by alkali and the heat of formation of its equivalent in nitric acid subtracted from the number obtained by titration. The weight of barium sulphate multiplied by 100 gives directly the number of calories to be subtracted.

Determination of the Water Value of the Apparatus.—The heat produced by combustion in the bomb is absorbed not only by the water of the calorimeter but also by the bomb, the stirring apparatus and the thermometer in contact with the water.

The amount of heat taken up by the apparatus depends upon the weight and the specific heat of the respective parts. Hence it is necessary to find the water value of the apparatus, that is, what weight of water would absorb the same amount of heat for the same rise in temperature.

The determination of the water value of the apparatus is made in two ways, one by calculation and the other by direct experiment.

Method of Calculation.—Multiply the weights of the different parts of the apparatus by their respective specific heats.

Calorimeter vessel, Brass.			
Vessel, 333. grammes.			
Stirrer, 124.5 grammes.			
Total, 457.5 grammes	× 0.093	=	42.55
Bomb,* steel, 999.75 grammes	× 0.1097	=	431.31
Platinum, 20.5 grammes	× 0 0324	=	.66
Lead, 9.6 grammes	× 0.031	=	.30
Thermometer, glass bulb, 4.09 grammes			
Tube, 29.36 grammes, one-fourth immersed, = 7.34 grammes			
Total glass, = 11.43 grammes	× 0 184	=	2.1
Mercury, 25.97 grammes,	× 0.033	=	8 07
Oxygen (20 atmospheres pressure).			
16.7 grammes	× 0 155	=	2.59
Water value =			488 11

* The weight of the enamel in the bomb was not known, its specific heat as determined by M. Martignon at the College of France is 0.2045. The water value is, there-

Method by Experiment.—Certain compounds whose heat of combustion is accurately known are burned in the calorimeter. This method has the advantage that the water value of the apparatus is determined directly by and under the same conditions as in ordinary combustion, but it has the disadvantage that exact heat of combustion of any compound is not known.

Comparisons by experiment of these two methods yield very close results.

Condition of the Coal.—For all other analyses it is convenient to have the coal in a finely pulverized condition. In making calometric determinations, however, this is quite undesirable. It has been found that, if fine dust from highly bituminous coal be burned in a current of oxygen, tar is always formed in addition to the gaseous products, and, in some cases, a separation of carbon as soot has been observed. To overcome this objection, it is sometimes necessary to compress the coal dust into tablets. W. Hemple* gives an illustrated description of a compresser used for this purpose. The one used in the metallurgical laboratory at the School of Mines is simple in construction, and consists of a hollow steel cylinder, 3 m.m. in thickness, 1.3 c.m. inside diameter, and 4 c.m. high, surrounded by a ring of solid steel, 7 m.m. thick, and 4 c.m. outside diameter, this ring is midway between the top and bottom of the cylinder. Into this cylinder a solid steel plunger is accurately fitted, having a top plate 9 m.m. thick and 4 c.m. diameter. The mould sets upon a base-plate 7 c.m. thick and 4 c.m. in diameter, having an upward projection of solid steel, 1 c.m. high, fitting accurately into the bottom of the mould cylinder. The mould, plunger, and base fit in a small screw press.

To form a compression tablet, the base-plate is put in position, and the mould placed upon and around the projection. The fine coal dust, a little over a gramme, is then poured into the mould, and the cylindrical plunger placed on the top. The whole is then submitted to pressure by an ordinary screw-press, and when sufficient power has been exerted to bind all the free particles together, the mould, base and plunger are removed from the press. The object of the solid ring around the mould is to permit of an easy

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fore, a little low, but the slight amount is of no vital importance, as one gramme difference in water value makes a difference of only .03 of 1 per cent. in the final result, which is within the limits of manipulation error.

* *Methods of Gas Analysis*, translated by L. M. Dennis, p. 356.

removal of the tablet from the mould; by placing the fingers beneath this ring but very little exertion is required to cause the mould to slide up on the plunger freeing it from the fine coal within, which then stands as a cylindrical core upon the projection from the base-plate.

A series of experiments is now being carried on to ascertain the relative efficiency of the Thompson calorimeter as compared to the Mahler bomb calorimeter.

METALLURGICAL LABORATORY, COLUMBIA COLLEGE SCHOOL OF MINES,
April 22, 1895.

ARGON.

RÉSUMÉ BY E. WALLER, PH.D.

AT the meeting of the Royal Society of England, on January 31, 1895, Lord Rayleigh and Mr. William Ramsay read a paper on the newly-discovered constituent of the atmosphere, which they have named argon (ἀργον, inactive). At the same meeting papers were presented by Mr. William Crookes on the spectrum of argon, and by Prof. Olszewski on the liquefaction and solidification of that substance. The papers contain essentially the entire record at present of the results of experiments on this material. A summary of the results may prove interesting.

DISCOVERY.

It was observed that the weight of one litre of "chemical nitrogen" was on the average 1.2505 grammes, whereas that of one litre of "atmospheric nitrogen" averaged 1.2575 grammes, a difference too large to be accounted for by "errors of experiment."

By "chemical nitrogen" they mean nitrogen obtained from various combinations, such as nitric oxide, nitrous oxide, ammonium nitrite, urea, etc., including magnesium nitride, the nitrogen of which had been absorbed from the air by incandescent magnesium.

"Atmospheric nitrogen" is the term applied to the nitrogen

left after extraction of the oxygen from the air by passing it over red-hot copper.

That the comparative lightness of the "chemical nitrogen" was not due to the presence of hydrogen or of monatomic nitrogen (N_1 instead of N_2), was proved by careful experiment.

Experiments upon the "atmospheric nitrogen" of ordinary air, and of air which had been subjected to atmolysis (diffusion), afforded the phenomena which were to be expected, if the ordinary atmosphere contained an admixture of a heavier gas, *i.e.*, the heavier gas was concentrated in the portion which had not diffused.

Preparation.

Definite volumes of "atmospheric nitrogen" were subjected to treatment calculated to remove the oxygen; these were: 1. Mixing with oxygen and "sparking" with the current from a Ruhmkorff coil, the oxidized nitrogen compounds being absorbed in an alkaline solution. 2. Passing the gas slowly over incandescent magnesium so as to form magnesium nitride.

Experiments (most conveniently managed by "sparking") showed that a small amount of gas (0.32 c.c. in 50 c.c., 0.76 c.c. in 100 c.c., etc.) remained unaffected by the treatment, the amount being in proportion to the amount of air taken.

On referring to the account given by Cavendish regarding his experiments on the composition of air (by "sparking"), it was found that he had recorded the presence of a small amount of unabsorbed gas, which he estimated as "not more than $\frac{1}{120}$ part of the whole."

The solubility of the gas in water prevented the data obtained from affording an exact index of the proportion in which it exists in the air. The proportion was calculated from other data as about 1 per cent.

Density.

A calculation based on the excess of weight of one litre of "atmospheric nitrogen" gave a density of 20.6 (density of hydrogen = 1). Not enough of the argon was obtained to fill the large globes used, but in these, when mixed with known amounts of oxygen, a calculation from the weights showed:

Density of argon obtained by "sparking," 19.7.

Density of argon obtained by magnesium, 19.9.

Solubility in Water.

100 volumes of water dissolved at 12° C., 3.94 volumes of argon (sparking).

100 volumes of water dissolved at 13.9° C., 4.05 volumes of argon (magnesium).

About 2½ times as soluble as nitrogen.

An examination of "water nitrogen" obtained from rain-water indicated that it was more than twice as rich in argon, which tends to confirm the preceding.

Ratio of Specific Heats.

By a determination of the velocity of sound in the gas, the ratio of the specific heat at constant pressure to that at constant volume was determined. It was found to be very nearly 1.66, from which it is concluded that the gas is one in which the kinetic energy is entirely that of translation, and it is therefore inferred that the gas is monatomic. The only other gas which has been found to behave similarly is mercury gas at a high temperature.

Spectrum.

Argon affords two spectra, which may be spoken of as a "blue" and a "red" spectrum. The latter is the most persistent, it being difficult to obtain the "blue" entirely free from the red, but not the reverse. The blue glow is produced by the negative spark, the red by the positive spark. In the blue spectrum Mr. Crookes counted 119 lines, in the red 80 lines. Of these, 26 appeared to be common to both. Only 1 or 2 of the lines observed approximated closely to lines in the nitrogen spectrum.

Argon, at a tension of 3 millimeters, gives the red spectrum with greatest luminosity and brilliancy. The most prominent lines under these conditions are at wave lengths 696.56 and 705.64. These lines are not, however, very prominent at atmospheric pressure. Under those conditions the most characteristic lines are in the neighborhood of F. At a lower tension than 3 millimeters or with a stronger current, the blue spectrum was obtained.

Liquefaction, etc., of Argon.

The following comparative data were obtained:

Substance.	Critical. Temp. below.	Critical. Pressure atmos.	Boiling point.	Freezing point.	Freezing pressure m.m.	Density of liquid at boiling point.
H_2, . .	— 220.0	20.0	?	?	?	?
N_2, . .	— 146.0	35.0	— 194.4	— 214.0	60	0.885
CO, . .	— 139.5	35.5	— 190.0	— 207.0	100	?
Argon A_1, .	— 121.0	50.6	— 187.0	— 189.6	?	about 1.5
O_2, . .	— 118.8	50.8	— 182.7	?	?	1.124
NO, . .	— 93.5	71.2	— 153.6	— 167.0	138	?
CH_4, . .	— 81.8	54.9	— 164.0	— 185.8	80	0.415

THEORETICAL.

All attempts which have hitherto been made to cause argon to enter into combination have been unsuccessful.* The phenomena when the gas is condensed to the liquid or the solid form, tend to indicate that it is not a mixture, and several other indications point to its elementary character. The ratio of the specific heats seem to show that it is monatomic. If monatomic, with a density of nearly 20, its atomic mass should be about 40, and it is difficult to assign to it its position in the periodic system of the elements.

On the other hand, the dual character of the spectrum would seem to indicate a nature more complex than could be concluded from the consideration of its other properties. Several have suggested that it may prove to be an allotropic form of nitrogen, possibly N_3, the density of which would be 1½ times that of ordinary N_2 (or about 21).

The investigation of this and other points is likely to be attended with great difficulties, but the results will assuredly be looked for with great interest.

Deboisbaudran states that he has studied out a classification of the elements, in accordance with which he postulates the existence of a "family" of elements of a non-metallic nature, devoid of the faculty of combining with other elements, having atomic masses 20.0945; 36.40 ± 0.08; 84.01 ± 0.20; and 132.71 ± 0.15 (assuming O = 16).

The first and second should be relatively abundant in nature. Argon would seem to be one of this group, according to his idea.

* Since this was written M. Berthelot has announced (*Compt. Rend.*, cxx., p. 581), that by exposing a mixture of benzene vapor and argon to the influence of the silent electric discharge, a combination was effected. The amount of the compound obtained was, however, too small for thorough examination.

In this connection the following communication to the Chemical Society of London, at the anniversary meeting, March 27, 1895, is of interest:

DISCOVERY OF HELIUM.—By PROF. W. RAMSAY, F.R.S.

In seeking a clue to compounds of argon I was led to repeat experiments of Hillebrand on clèveite, which, as is known, when boiled with weak sulphuric acid, gives off a gas hitherto supposed to be nitrogen. This gas proved to be almost free from nitrogen; its spectrum in a Pflücker's tube showed all the prominent argon lines, and, in addition, a brilliant line close to, but not coinciding with, the D lines of sodium. There are, moreover, a number of other lines, of which one in the green-blue is especially prominent. Atmospheric argon shows, besides, three lines in the violet which are not to be seen, or if present, are excessively feeble, in the spectrum of the gas from clèveite. This suggests that atmospheric argon contains, besides argon, some other gas which has as yet not been separated, and which may possibly account for the anomalous position of argon in its numerical relations with other elements.

Not having a spectroscope with which accurate measurements can be made, I sent a tube of the gas to Mr. Crookes, who has identified the yellow line with that of the solar element to which the name "helium" has been given. He has kindly undertaken to make an exhaustive study of its spectrum.

I have obtained a considerable quantity of this mixture, and hope soon to be able to report concerning its properties. A determination of its density promises to be of great interest.

THE SPECTRUM OF THE GAS FROM CLÈVEITE. By WILLIAM CROOKES, F.R.S.

By the kindness of Prof. Ramsay, I have been enabled to examine spectroscopically two Pflücker tubes filled with some of the gas obtained from the rare mineral clèveite.* The nitrogen had been removed by "sparking." On looking at the spectrum, by far the most prominent line was seen to be a brilliant yellow one apparently occupying the position of the sodium lines. Examination

* Clèveite is a variety of uraninite, chiefly a uranate of uranyle, lead, and the rare earths. It contains about 13 per cent. of the rare earths, and about 2 5 per cent. of a gas said to be nitrogen.

with high powers showed, however, that the line remained rigorously single when the sodium lines would be widely separated. On throwing sodium light into the spectroscope simultaneously with that from the new gas, the spectrum of the latter was seen to consist almost entirely of a bright yellow line, a little to the more refrangible side of the sodium lines, and separated from them by a space a little wider than twice that separating the two sodium components from one another. It appeared as bright and as sharp as D_1 and D_2. Careful measurements gave its wave-length 587.45; the wave-lengths of the sodium lines being D_1, 589.51, and D_2, 588.91. The differences are therefore:

	Wave-lengths.	Differences.
D_1,	589.51	
		0.60
D_2,	588.91	
		1.46
New line,	587.45	

The spectrum of the gas is, therefore, that of the hypothetical element helium, or D_3, the wave-length of which is given by Angstrom as 587.49, and by Cornu as 587.46.

Besides the helium line, traces of the more prominent lines of argon were seen.

Comparing the visible spectrum of the new gas with the band and line spectrum of nitrogen, they are almost identical at the red and blue end, but there is a broad space in the green where they differ entirely. The helium tube shows lines in the following positions:

	Wave-length.	
(*a*) D_3, yellow,	587.45	Very strong. Sharp.
(*b*) Yellowish green,	568.05	Faint. Sharp.
(*c*) Yellowish green,	566.41	Very faint. Sharp.
(*d*) Green,	516.12	Faint. Sharp.
(*e*) Greenish blue,	500.81	Faint. Sharp.
(*f*) Blue,	480.63	Faint. Sharp.

I have taken photographs of the spectrum given by the helium tube. At first glance the ultra-violet part of the spectrum looks like the band spectrum of nitrogen, but closer examination shows considerable differences. Some of the lines and bands in the nitrogen spectrum are absent in that from the helium tube, whilst there are many fine lines in the latter which are absent in nitrogen. Accurate measurements of these lines are being taken.

CONTRIBUTIONS FROM THE MINERALOGICAL DEPARTMENT OF COLUMBIA COLLEGE.—XXI.

By ALFRED J. MOSES.

The Pyramids of Zincite.

All measurements of crystals of natural oxide of zinc have been described as unsatisfactory, and the unit upon which the accepted axis ratio has been determined is a certain "very small, brown, artificial crystal from the furnace at Lerbach, Harz," measured by Prof. Rinne.* In this

$$c. \wedge p. = 61° 54' \text{ and by calculation } p. \wedge p.' = 52° 21'.$$

E. S. Dana† measured certain natural crystals from the Bement collection, obtaining angles which he describes as approximate:

$$c. \wedge p. = 65° 20'; \; p. \wedge p.' = 53° 43'; \; p. \wedge p.'' = 54° 2'.$$

Prof. Dana figures the crystals as hemimorphic unit pyramid prism and base, Fig. 1.

More recently, Mr. P. Grosser‡ measured a rather large crystal fragment showing three pyramidal and two prismatic faces, and obtained results described as "very inexact," but still undoubtedly not the unit form of Rinne or Dana.

$$c. \wedge p. = 55° 38'; \; p. \wedge p.' = 48° 50'.$$

I have measured recently two crystals not heretofore described —one the property of Mr. F. L. Nason; the other the property of Columbia College. The results are not perfectly satisfactory, and yet are sufficiently accurate to prove beyond question the existence of two different pyramids on natural crystals.

The Nason crystal yielded fairly good reflections from two ad-

* Rinne, *Neues Jahrb. Min.*, 1884, II., 164.

† *Am. J. Sci.*, 3 S., XXXII., 389.

‡ *Zeit. f. Kryst.*, XX., 354, 1892.

jacent pyramid faces. The maximum reading was 54° 51′, the minimum 54° 14′, and the average of ten was 54° 42′ = $p. \wedge p'$. The form is shown in Fig. 2.

The Columbia College crystal yielded bright reflection from a basal cleavage plane, but only an indistinct blur from the pyramidal planes. By attaching bits of mica, somewhat better reflections were obtained. The measurements between the basal plane and three different pyramidal planes varied in each case less than one degree. The averages were:

$c. \wedge p.$ without mica 55° 26½′.

$c. \wedge p.'$ with mica 55° 34⅔′.

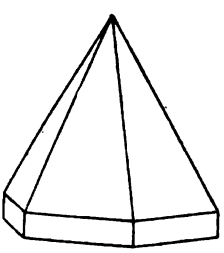
$c. \wedge p.''$ with mica 55° 59⅔.

Or, allowing equal weight, an average value of

$$c. \wedge p. = 55° 40'.$$

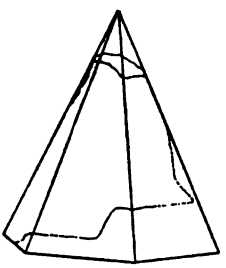
The form is shown in Fig. 3.

FIG 1.



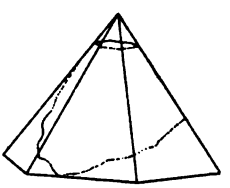
Bement.

FIG. 2.



Nason.

FIG. 3.



Columbia College.

The measurements prove the occurrence of at least two pyramids, which relatively to the artificial unit crystal are probably $(\frac{5}{4}, 50\bar{5}4)$ and $(\frac{4}{5}, 40\bar{4}5)$.

	$c. \wedge p.$	$p. \wedge p'.$	mic.
Artificial unit (Rinne), . .	61° 54′	52° 20′	1.6219
Pyramid $\frac{5}{4}$ calculated, . .	66° 52′	54° 46′	2.0273
Nason's crystal (Moses), . .	.....	54° 44′	2.0150
Bement's crystal (Dana), . .	65° 20′	54° 2′	1.88 approx.
Pyramid $\frac{4}{5}$ calculated, . .	56° 17′	49° 9′	1.2975
Grosser's crystal, . . .	55° 38′	48° 50′	1.27 approx.
College crystal (Moses), . .	55° 40′	.....	1.27 approx.

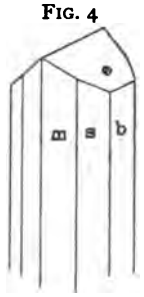
Atacamite from Globe, Arizona.

Specimens of atacamite, $Cu_2ClH_3O_3$, sent to Columbia College by Mr. A. L. Walker, Consulting Engineer of the Old Dominion Copper Company, were found chiefly in the second and fifth levels of the Globe Mines, Gila County, Arizona.

One specimen consists of a crust of atacamite composed principally of more or less perfect, very dark green crystals. Upon this crust there has been deposited a white clay-like material which has imparted a rounded botryoidal appearance to the groups of crystals. Upon removal of the white material, the crystals are found to be bright and sharp. The atacamite rests upon a fine grained sand rock, seamed and impregnated with atacamite.

Another specimen was composed chiefly of calcite, with a little native copper and cuprite. A large crystal of atacamite, approximately 13 × 5 × 2 mm. was embedded in the calcite.

Fig. 4



The crystals are simple, and vary very little; the large crystal mentioned is flattened parallel to *b*, but the rest are as in Fig. 4. No doubly terminated crystals were found. The unit dome $\{011\}$ is very bright on the large crystal, but on many of the others it is rough and irregular, and at first sight gives the impression that the crystals have been broken. The only observed forms were

$$b\{011\}\ 1\text{—}\breve{i};\ m\{110\}\ I;\ s\{120\}\ i\text{—}\bar{2};\ g\{010\}\ i\text{—}\breve{i}.$$

Crystals of Tartar Emetic $C_4H_4O_6$ (SbO) K + ½ H_2O.

The two varieties of tartar emetic obtained from dextro-rotary and laevo-rotary racemic acid were obtained by Pasteur in orthorhombic crystals, which differed from each other in the development of the planes of one sphenoid or the other of a certain pyramid. The angles were said to be equal, and it was definitely stated* that "sometimes the crystal is holohedral, that is to say the eight pyramidal faces are equally developed. Then the crystals can only be distinguished by determining the rotation of a water solution in the polariscope."

Prof. C. E. Colby submitted to me some crystals of the dextro

* M. L. Pasteur, *Ann. Chim. et Phys.*, 3 S., XXVIII., 85. 1850.

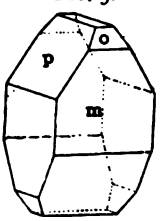
tartar emetic which differed from the figure of M. Pasteur considerably and chiefly in this that the larger sphenoid was of quite different angles from the smaller, and so related that a calculation based on the angles obtained yielded

More obtuse sphenoid (larger), $\breve{a} : \breve{b} : \dot{c} = 0.9578 : 1 : 1.1048$.

More acute sphenoid (smaller) $\breve{a} : \breve{b} : \dot{c} = 0.9578 : 1 : 2.2151$.

That is, if the former be taken as the unit, the latter is evidently the $2, \{ 221 \}$. This is also evident from the angles measured and calculated:

FIG. 5.



			Measured.	Calculated.
$m \wedge m'''$	or	$(110) \wedge (\bar{1}10)$	$= 92° 28'$	.....
$p''' \wedge p'$	or	$(\bar{1}11) \wedge (1\bar{1}1)$	$= 64° 6'$	.....
$o \wedge o''$	or	$(\bar{2}21) < (221)$	$= 34° 41'$	$34° 46'$

The usual form of the crystals was that shown in Fig. 5. There was an easy basal cleavage.

A NOTABLE SPECIMEN OF ENARGITE.

It is believed that a specimen of enargite (Cu_3AsS_4) presented to the Mineralogical Department of Columbia College by Mr. C. H. Hand, and found in the Bell Stow Mine, Missoula County, Montana, is unequalled in size and perfection of crystals. Fig. 6 shows the specimen approximately full size, and Fig. 7 is a representation of the largest crystal with the unit (orthorhombic)

FIG. 6.

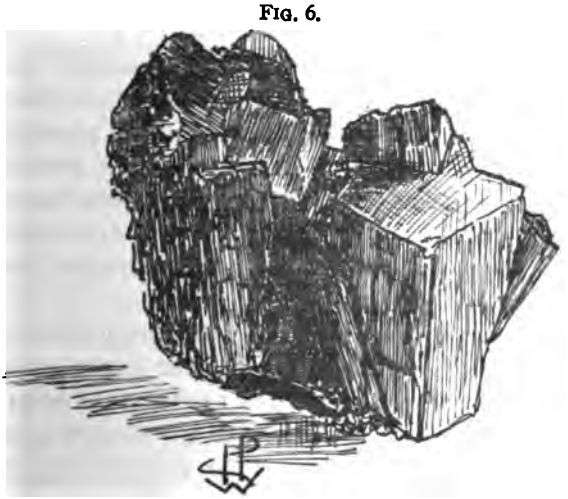
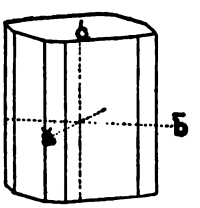


FIG. 7.



axes, the occurring faces being the prisms { 110 } and { 120 }, and the pinacoids { 001 } and { 100 }.

This crystal measures closely 28 m.m. (vertical) × 24 m.m. (macro) × 20 m.m. (brachy), the faces are very smooth, as if burnished, and bluish-black in color, like columbite. In one or two places a thin scale has peeled off, leaving a smooth black surface without the bluish tint. The vertical faces are slightly furrowed, and across the base are several fine striæ parallel to the macro axis.

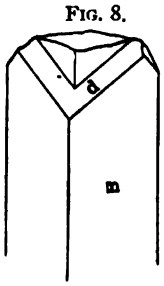
There are several other crystals on the same specimen, showing the same association of forms, and almost as perfect and sharp-angled.

Hollow Pseudomorphs of Quartz After an Unknown Mineral.

In the crystallized quartz found under the trap rock at McDowell's Quarry, Upper Montclair, N. J., there are found prismatic cavities lined with white opaque silica. The cavities vary in size, a frequent length being approximately one to one and one-half inches but the rhombic cross-section varying from about one inch to one-eighth or one-sixteenth of an inch on the longer diagonal.

Frequently there is a definite radiation of the cavities from a common centre. In no instance have any traces of the original mineral been observed, although small crystals of stilbite are sometimes found in and about the cavities.

Fig. 8.



Casts were made of several cavities and these were measured with the hand goniometer. In most instances the casts showed four longitudinal or prismatic planes *m*, Fig. 8, and one plane *d* parallel to the longer diagonal as figured. Planes parallel to the shorter diagonal were indistinctly suggested. The plane *b* did not in any of the casts obtained form a complete termination but was interrupted by another growth of the prism.

In spite of the roughness of the plaster casts, the measurements of the prismatic angle with the hand goniometer upon four casts of different cavities varied only between 117° and 120° and the mean value of several measurements of each were, to the nearest half degree:

118° }
119° }
119° } Average say 118° 30′ approximate.
118½° }

The angle $m \wedge b$ yielded a mean measurement of 139° approximate.

It would seem that some unknown mineral occurring in radiating crystals of approximately the form shown in the figure had first been incrusted with a uniform layer of white opaque silica and that subsequently the original mineral had been completely dissolved away, leaving a shell of quartz. The crystalline quartz must have filled in all interstices before the dissolving away of the unknown mineral.

I am unable to suggest the original mineral. The symmetry seems to call for a monoclinic species, the angles are not far from those of orthoclase in which *m* would be the unit prism and *b* the orthodome, 201, but this would be an unusual combination and the radiating structure is also opposed to the supposition.

MONAZITE AND ORTHOCLASE FROM SOUTH LYME, CONN.

By W. D. MATTHEW.

During the last Easter vacation, 1894, Mr. Gilbert van Ingen and I visited a number of quarries and cuts along the line of the railway between New Haven and New London, to see the contacts between the intrusive granites and the gneisses. The pegmatite veins at these contacts afforded a number of minerals, among which was a large crystal of monazite, of which Fig. 1 represents the actual and Fig. 2 the restored form. It shows the faces *a* $(i\text{-}\bar{i})$, *b* $(\bar{i}\text{-}i)$, *w* $(-1\text{-}\bar{i})$, *u* $(2\text{-}\bar{i})$, *v* (1) and *s* ? $(3\text{-}\bar{3})$, the last rough and striated and only approximate. The determinations were made with a hand goniometer. It is wedge-shaped, from the prominence of the macro-pinacoid, *a*, and the positive unit hemi-pyramid, *v*. A twinned lamella, $\| a$, is intercalated in the crystal. A brilliant

FIG. 1.

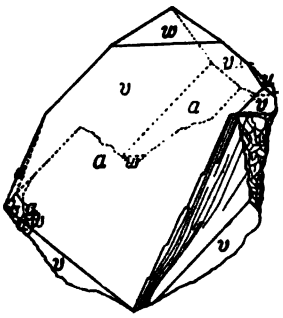
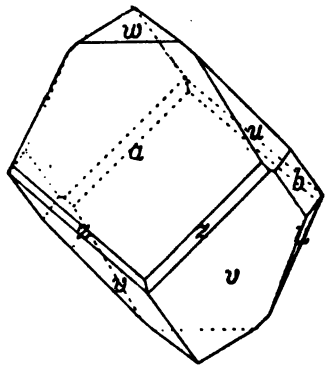


FIG. 2.

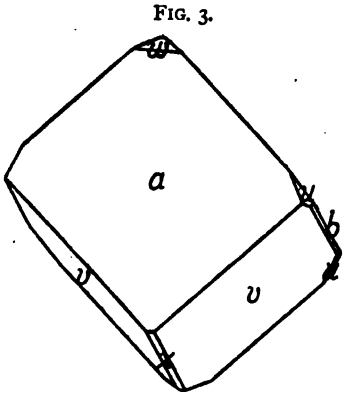


Monazite, South Lyme, Conn.

cleavage or parting, $\| c$, is noticeable. Dimensions 22½ by 22 × 12 mm. Specific gravity, with a small amount of feldspar attached, 4.9. Color reddish-brown, nearly opaque, with resinous internal reflections. Found by Mr. van Ingen. Occurs in quartz-orthoclase pegmatite, along with titanite, menaccanite, molybdenite, biotite, albite, etc. It is associated especially with the biotite of the rock. The specimen is now in the mineral collection of Columbia College.

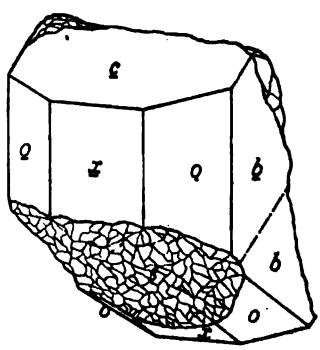
Prof. Kemp, on a later visit to the locality, found a number of smaller monazite crystals, more or less perfect, which he has kindly placed in my hands for study. One of these, showing the characteristic simple form, with *a* and *v* slightly modified by other faces, is figured here (Fig. 3).

FIG. 3.



Monazite, South Lyme, Conn.

FIG. 4.



Orthoclase, South Lyme, Conn.

The orthoclase of the pegmatite veins is in large and well-developed crystals. One shows the faces $b\,(i-i)$, $c\,(O)$, $m\,(I)$, $z\,(i-\bar{3})$, $x\,(1-i)$, $y\,(2-i)$, $n\,(2-i)$ and $O\,(1)$. Another one, about $5\frac{1}{2} \times 4\frac{1}{2}$ inches, is twinned parallel to the basal pinacoid (Fig. 4), with the faces a, b, o and x developed.

MINERALOGICAL LABORATORY, Columbia College,
April 10, 1895.

CRYSTALLINE COMPOUNDS OF SUCROSE, DEXTROSE AND LEVULOSE.

BY F. G. WIECHMANN, PH.D.

IN the SCHOOL OF MINES QUARTERLY, Vol. XIII., No. 2, the writer has given an account of a crystalline magma, which had been formed under the influence of sunlight, in an inverted sucrose-solution. Mention was made at the time of the writer's intention to separate this magma into a solid and a liquid portion and to determine the composition of the crystals.

This has been done, and here shall be given the results obtained by analysis of these crystals, A, and, besides, the data gained by examination of two other crystal specimens obtained in the same manner from inverted sucrose-solutions.

The separation of the crystals from the adhering liquid was effected by placing the magma in a small apparatus especially made for the purpose. This consisted essentially of two chambers, separated by a perforated brass plate, a brass-wire screen and three layers of fine silk bolting-cloth.

After the magma had been placed into one of these chambers, the apparatus was securely screwed together and then placed into a large sugar centrifugal-machine making about 1000 revolutions per minute.

Spinning at this rate was continued for nine hours or more, until no further fluid could be separated from the crystals, and these felt perfectly dry and presented a solid, compact appearance.

Analysis was effected by the writer's method.* The specific rotatory power of levulose was taken as -93.8.

* SCHOOL OF MINES QUARTERLY, Vol. XIII., No. 3.

	A.	B.	C.
Sucrose,	4.67	9.86	16.33
Dextrose,	59.18	54.29	60.46
Levulose,	34.68	34.84	21.36

In sample C, the liquid which was removed from the crystals by the spinning was also analyzed, and was found to consist of:

Sucrose,	31.82
Dextrose,	22.16
Levulose,	40.86

THE SINKING OF THE LADD SHAFTS.

By GEORGE S. RICE, E.M.

At Ladd, which is in Bureau county, Illinois, the coal measures are overlaid by a drift deposit, 160 to 200 feet thick, of clay, sand, and gravel, interspersed with boulders, sometimes of large size. It seems to have been the accumulation at the bottom of an ancient lake, as the material is in more or less regular layers containing shells and pieces of float-wood which were found all the way down to the solid rock. The surface of the latter was evidently scoured by the great glacier and is level, if not slightly basin-like in form, as indicated by the prospect drill-holes. The surface drains slowly till it reaches the bluffs of the Illinois river, which is distant, as the water flows, about eight miles from the shafts.

The result of this slow drainage above open sandy strata, and a slightly basin-like rock bottom, is to make the drift water-soaked and full of pockets of quicksand.

The coal seam worked at present is the third from the top, geologically, No. 2, and in the Ladd shafts is 460 feet from the surface, but after the 160 feet of drift is pierced, sinking presents no especial difficulties.

The officials of the Whitebreast Fuel Company were made aware by their prospect holes that water was to be encountered, but did not expect the enormous quantity nor the treacherous ground, consequently, the beginning of the work was marked by several unsuccessful attempts. The ordinary methods of cribbing and spiling were first tried, and then an ordinary timber drop shaft.

But, in addition to large quantities of water, much difficulty was experienced on account of the variable nature of the ground, alternating hard and soft strata, the presence of boulders, etc. This made a drop shaft impracticable, since it would settle unevenly and could not be controlled.

Success was finally attained by introducing a heavy steel shoe, which was forced ahead of the lining by jackscrews, additions being made in sections to the lower edge of the lining. In principle this is similar to the method of tunneling in soft ground with the use of an advance shield, and is almost identical with the old Guibal system, first employed for shaft sinking about 1856, with this difference; that in the Ladd shafts, the shoe was rectangular instead of round.

Four shafts were begun, one after another, the fourth having actually reached solid rock, and lacking but little of completion, when the curbing near the bottom gave way, and a strong inrush of sand and water destroyed six months' work.

The first shaft was started June 1, 1888, by experienced sinkers. The customary method of sinking through drift was employed, that is, excavation was followed closely by timbering with 2-inch by 12-inch planks laid flat. The water was handled first with barrels. At a depth of 50 feet water and sand burst up from the bottom, and the cribbing became so swung and twisted that the shaft had to be abandoned.

The second shaft was started in the latter part of June, 10 feet west from the first, which was to be used as a sort of sump until the second shaft had gone below it. When the second shaft did get below the first, great trouble was again experienced from water and sand. Spiling was tried, driven in advance of the timbering around the edges, but the rushes of sand and water threw them out. Meantime a pump was put in; but at a depth of about 70 feet the rushes were so strong it was found that ordinary methods would not do. A heavy wooden shoe was proposed, to be sunk from this point, building the curbing on top of it, in other words, making a drop-shaft through the very soft ground from the point where the ordinary method had stopped. The ground back of the gap where the successive rounds of timbers were added on, as the drop-shaft sank, was to be kept back by a stationary shield of plank outside the curbing. The shoe was made and started; it could not be made to sink evenly, and almost at once became dis-

torted and stuck, and the rushes became so bad, that the stationary curbing above was pulled apart and the shaft was so racked that it was abandoned.

Mr. Phillips now designed the steel-plate sinking shoe and the plan of suspending the curbing on which he received Patents No. 424,819 and No. 424,820. The first experimental shoe may be briefly described as a steel-plate box, open top and bottom, the upper part inclosing the bottom of the curbing, the lower part divided by plate braces into six compartments. The shoe to be hung when it was so needed, by chains to lines of iron rods running from trusses across the shaft at the surface. These rods were in the corners of the shaft and also helped support the curbing by means of cross timbers every 10 feet, through which they ran. The timbers were set into the curbing, and later when the curbing rested on the solid rock were to be cut out. While the shoe was building, the shaft in which it was to be placed, No. 3, was started about August 1, 1888. The cribbing was again of 2-inch by 12-inch planks laid flat, with two temporary lines of buntons of 6-inch by 8-inch timbers with 10-inch intervals. The outside dimensions of the shaft were 12 by 16 feet. It was planned when the shaft reached the solid rock to timber up with an inner cribbing 8 inches thick, puddling between the two cribs, leaving a shaft-way 6 feet 3 inches by 10 feet 6 inches, divided by a partition 6 inches thick. The shaft was carried down 50 feet by ordinary methods before the shoe was ready.

The latter was taken down piece by piece, put in place and bolted together, which proved a hard job in the mud and water, but which was successfully accomplished. The shoe and the method of hanging the curbing proved a decided success, and sinking steadily proceeded to a depth of 125 feet. At this point, however, such a burst of sand and water came up from the bottom that it drove the men from their work. While the shoe had worked well, it had proved to be too light for the conditions and the compartments too large; so it was decided to let the shaft stand for the time being and put down another shaft, which might lessen the water and thus permit the work on this to be resumed.

Accordingly an improved and heavier shoe, with 15 compartments, instead of 6, was built, and on January 8, 1889, the fourth shaft was started, located about 50 feet east of the first. This shaft made good progress, considering the severe winter weather, till a

depth of 138 feet was reached, which was on March 8th, just two months from the start. But here there was a tremendous burst of water and sand, the water amounting to over 640 gallons per minute, which soon drowned out a large Deane pump with a 6-inch discharge, and a Blake with a 4-inch discharge. Before another pump could be brought into action, the water was 80 feet up the shaft.

Then followed long delays, while certain pistonless pumps were tried and found wanting. Very little sinking was done till May 9th, when it progressed slowly, meeting great difficulties. Boulders were encountered, which got under the edge of the shoe and had to be blasted, and bad rushes of sand and water. The sand added immensely to the difficulties of pumping. At times a man had to be kept constantly at work cleaning the suction strainers so they would draw. It also cut the valves and linings of the pumps, so that the pumps had to be changed and completely repaired at least once a week. The removal of the enormous bodies of sand and water from around the shaft was felt clear to the surface, which sank a foot or more in places over a large area, sometimes on one side sometimes on another. This caused the shaft to swing, and threw great strains on the supporting trusses and on the curbing. This was further aggravated by the uneven pulls of the shoe, due to its being hard perhaps only under one corner or side. These strains sometimes forced the cribbing planks from the level, and it would be necessary to level up again so that the shoe might descend vertically and the next courses would be tapered, that is, the planks would be adzed so as to be thinner at one end than at the other. This necessarily weakened the plank, and together with the strains from the general distortion of the curbing, was undoubtedly the cause of its giving away later. However, the shaft progressed to a depth of 158 feet, which was reached May 20th, and brought the crib within 4 feet of the rock. At this juncture the pumps on hand completely played out, and another delay ensued till June 26th, four days after which the rock was reached.

The shoe was then secured, the compartments were cut out, and the timbering carried down to the rock. The rock at this point proved to be 3 feet thick, and this was also penetrated to the shale immediately below. From this point the inside lining and puddling and permanent partition was begun, working upward from

the bottom and removing the temporary buntons and cross-timbers as the work advanced. The inner lining had been built up about 8 feet, when suddenly the curbing gave way just above it, at the east end, flooding the shaft with sand and water. Fortunately this happened at lunch time when all were on top but two men who were looking after the pumps; these barely got out, for in a few minutes the shaft had filled half way up.

This happened July 14, 1889. Not discouraged, the company soon arranged for another attempt. The shoe having proved successful, a duplicate one was ordered, but thicker cribbing was used for the lower part, namely, 2-inch by 14-inch planks flat. At one time the experiment was tried of alternating 2-inch by 12-inch and 2-inch by 14-inch plank, made flush inside, but presenting a rough exterior; the idea being to give the shaft a better hold on the ground, also to make it less easy for the sand and water to wash down outside the cribbing. However, in practice it did not prove of any particular advantage in these respects. On the other hand, it occupied as much space as a solid 14-inch wall, and was not so strong; thereafter, 2-inch by 14-inch timber was used exclusively. Another improvement, was in the use of hangers or iron lugs spiked to the cribbing, instead of the oak cross-pieces which had been set into the cribbing, thereby weakening it, and which were often broken under the pull, and also were in the way in handling the pumps. The shaft was located 100 feet east of the fourth attempt. As a daily journal was kept by Mr. James Anderson, then engineer of the company, of all attempts after the third, and as this sinking was typical of the difficulties, the diary will be given unchanged and uncolored by the views of the writer, except for such slight additional words as are necessary for clearness:

August 9.—Shoe arrived from Chicago; unloaded and put it together in place.

August 10.—Sunk shoe down into the ground and moved trusses into place; sunk 4 feet through grade filling. Depth, 4 feet.

August 11.—Got tower up and started sinking, 3 P.M.; sunk 4 feet through grade filling and soil. Depth, 8 feet.

August 12.—Put in hangers and rods, and started buntons in east end; sunk 7 feet through yellow clay. Depth, 15 feet.

August 13.—Buntons now in both ends and going in regular fashion; sunk 7 feet through 4 feet yellow clay, 3 feet blue clay. Depth, 22 feet.

August 14.—Some water; handled by barrels; amount of water, 3 gallons per minute; sunk 6 feet through blue clay. Depth, 28 feet.

August 15.—No trouble; water 3 gallons per minute; sunk 5 feet through blue clay and gravel. Depth, 33 feet.

August 16.—No trouble; water 3 gallons per minute; sunk 4 feet through muddy clay. Depth, 37 feet.

August 17.—No trouble; water 3 gallons per minute, sunk 5 feet through blue clay. Depth, 42 feet.

August 18.—Water came in fast at 9.30 P.M.; put in a No. 9 Blake pump; water 104 gallons per minute after tapping; sunk 5 feet through blue clay and sand. Depth, 47 feet.

August 19—No trouble; water 104 gallons per minute; sunk 4 feet through blue and yellow clay, sand and gravel. Depth, 51 feet.

August 20.—Sand all around south side and one-half of east end; hard clay and gravel under the rest, causing rushes. We do not dig out below press plates; water averaged 90 gallons per minute; sunk 5 feet through clay, sand and gravel. Depth, 56 feet.

August 21.—We bored 2-inch auger holes to relieve pressure and prevent rushes; did not do much good; drove spiles but rushes threw them out again; water averaged 104 gallons per minute; sunk 3 feet through clay, sand and gravel. Depth, 59 feet.

August 22.—Caved clear to the surface at the east end; a crack in the curbing was caused by rushes below the last clamp; shaft swung 6 inches out of plumb, inclining to west; water averaged 104 gallons per minute; sunk 1½ feet through clay, sand and gravel. Depth, 60½ feet.

August 23.—The material is getting soft all over, principally sand and gravel; the shoe sets square, and we also got the timbering leveled; water 140 gallons per minute; sunk 1½ feet through clay, sand and gravel. Depth, 62 feet.

August 24.—Had to stop on account of shortage of suspending rods; put in a Deane pump in the west end; the trusses are pulled down about 1 foot; water 140 gallons per minute; sunk none. Depth, 62 feet.

August 25.—Have now good solid clay all around, except under the northeast corner, where it is sand as yet; water 140 gallons per minute; sunk 2½ feet through clay and sand. Depth, 64½ feet.

August 26.—Rushes of sand and water occurred all day; water 140 gallons per minute; sunk 2½ feet through clay and sand. Depth, 67 feet.

August 27.—Had a very bad rush of sand, filling about 8 feet up the shaft; trusses almost broke down; water averaged 140 gallons per minute; sunk none. Depth, 67 feet.

August 28.—Cleaned out the rush and blocked with wood between timber and shoe in place of jack-screws; withdrew the pumps; started to tear down trusses; shaft filled with water.

August 29.—Finished tearing down; got leveled up for new trusses.

August 30.—Started to build up trusses and top works.

August 31.—Finished them and started pumping out water in shaft.

September 1.—Got the water all pumped out and shoe cleaned out ready for sinking; water still coming in at rate of 140 gallons.

September 2.—Rushes of sand with the water all day; started a Nye pump in the caved-in shaft of the previous attempt, located about 50 feet away, to try to relieve the pressure of water; water 140 gallons per minute; sunk 1 foot through clay, gravel and sand. Depth, 68 feet.

September 3.—Same as yesterday; sand running up from a hole in the northeast corner; lowered the water in the neighboring shaft to 85 feet from the surface, so it

is 17 feet below bottom of present shaft, but without any effect in relieving from water; water averaged 140 gallons per minute; sunk 1½ feet through sandy clay and sand. Depth, 69½ feet.

September 4.—Got through with the sand-pocket at northeast corner, but as a consequence of the rushes of the past few days, a hole came to the surface, causing the upper part of the shaft to swing 2½ feet east; threw in bales of hay till it stopped running, then filled up with clay; water 140 gallons per minute; sunk 2 feet through sandy clay and sand. Depth, 71½ feet.

September 5.—Got all the water cut off from below; what there is comes in through the timbering; water 140 gallons per minute; sunk 2½ feet through sandy clay with gravel pockets. Depth, 74 feet.

September 6.—No trouble; water 108 gallons per minute; sunk 3 feet through blue clay. Depth, 77 feet.

September 7.—No trouble; water 83 gallons per minute; sunk 3 feet through blue clay. Depth, 80 feet.

September 8.—No trouble; lowered pumps and water in neighboring shaft 20 feet, making water 105 feet from surface; water 70 gallons per minute; sunk 2 feet through blue clay. Depth, 82 feet.

September 9.—No trouble; water 70 gallons per minute; sunk 3 feet through blue clay. Depth, 85 feet.

September 10.—No trouble; water 70 gallons per minute; sunk 3 feet through blue clay. Depth, 88 feet.

September 11.—No trouble; water 83 gallons per minute; sunk 3½ feet through blue clay and sandy silt. Depth, 91½ feet.

September 12.—No trouble; water 83 gallons per minute; sunk 3 feet through sandy silt. Depth, 94½ feet.

September 13.—Very fine sand running in with the water; water 104 gallons per minute; sunk 2½ feet through sand, very fine. Depth, 97 feet.

September 14.—Some small rushes at east end; lowered Nye pump in neighboring shaft 10 feet; water 104 gallons per minute; sunk 2 feet through sand and gravel. Depth, 99 feet.

September 15.—Small rushes again on east side, and one on south side; had to split a boulder in the southwest corner; water 104 gallons per minute; sunk 2½ feet through sand, gravel, and clay. Depth, 101½ feet

September 16.—No more rushes, but still pretty soft on east end, so we cannot dig below shoe; hard jacking; water 83 gallons per minute; sunk 2½ feet through cemented clay and gravel. Depth, 104 feet.

September 17.—Hard now all over; cannot make any room for shoe, as sand above is so very fine that it washes down through the smallest cracks; water 83 gallons per minute; sunk 2 feet through cemented clays and gravel. Depth, 106 feet.

September 18.—Had a bad rush in the northwest corner, filling the shoe with fine sand, and causing at the surface a circular cave 100 feet north of shaft; water 83 gallons per minute; sunk 2 feet through sandy blue clay with boulders. Depth, 108 feet.

September 19.—Had some large boulders, but the clay, while soft and sandy, is quite tough, and it seems probable that on jacking the shoe through it, the rushes will be cut off; water 70 gallons per minute; sunk 2 feet through sandy blue clay with boulders. Depth, 110 feet.

September 20.—Lots of little boulders but good jacking; water all cut off from the bottom; water 56 gallons per minute; sunk 4 feet through sandy blue clay with boulders. Depth, 114 feet.

September 21.—Same conditions as yesterday; water 56 gallons per minute; sunk 4 feet through sandy blue clay with boulders. Depth, 118 feet.

September 22.—No difficulties; water 42 gallons per minute; sunk 3½ feet through mucky clay. Depth, 121½ feet.

September 23.—Changed Blake pump from east end to the centre and hung a Deane pump in east end; water 42 gallons per minute; sunk 3 feet through mucky clay Depth, 124½ feet.

September 24.—No difficulties; the mucky clay started to swell or heave up in bottom of shoe; water 42 gallons per minute; sunk 4½ feet through mucky clay. Depth, 129 feet.

September 25.—No trouble; for some reason the neighboring fourth attempt shaft is making far more water than this shaft; water 42 gallons per minute; sunk 5½ feet through mucky clay. Depth, 134½ feet.

September 26.—Put in another Blake pump in place of one removed for repairs; water 42 gallons per minute; sunk 5½ feet through mucky clay. Depth, 140 feet.

September 27.—No trouble; lowered Deane pumps; water 42 gallons per minute; sunk 4½ feet through 3 feet mucky clay and 1½ hard pan. Depth, 144½ feet.

September 28.—Lowered Blake pump; broke lever; struck the large stream at 1.30 P.M.; running 500 gallons per minute; first rush brought about 10 barrels of sand; started the Deane pumps and kept the water down; water after rush 500 gallons per minute; sunk 2½ feet through sandy clay. Depth, 147 feet.

September 29.—Lowered the west Deane; water now coming very clear; water 420 gallons per minute; sunk 2 feet through greenish clay. Depth, 149 feet.

September 30.—Lowered both Deane pumps; the water all coming up as yet in the southwest corner and clear; water 350 gallons per minute; sunk 3 feet through clay with pockets of gravel. Depth, 152 feet.

October 1.—Lowered east Deane and the Blake pumps; are now about the level of the water-bed; water 350 gallons per minute; sunk 4 feet through sandy clay. Depth, 156 feet.

October 2.—The discharge hose blew off the east Deane pump three times; at the same time the Blake pump played out, causing six hours delay; water clear and gravel not running; water 350 gallons per minute; sunk 3½ feet through gravel. Depth, 159½ feet.

October 3.—The west Deane pump refuses to work, so we put in one more Blake pump; the water is coming in from all over; gravel has cement bands, sometimes running nearly across the whole bottom; water 350 gallons per minute; sunk 2½ feet through gravel. Depth, 162 feet.

October 4.—The gravel being cemented together in cakes, it is very tough digging and jacking; the shaft is in good shape, no pulling; water 350 gallons per minute; sunk 3 feet through gravel. Depth, 165 feet.

October 5.—Getting into the blue shale overlying the limestone; water 350 gallons per minute; sunk 3 feet through 2 feet of gravel and 1 foot of shale and gravel. Depth, 168 feet.

October 6.—Got shoe on to rock; water cut off from under shoe; water 350 gallons per minute; sunk 2 feet through shale Depth, 170 feet.

October 7.—Getting into rock, and some of compartments of shoe removed; pumps bothering; water 310 gallons per minute.

October 8.—Getting more sump room in rock, and timbered down through shoe on to the rock; water 310 gallons per minute.

October 9.—Got all the shoe braces out, and got farther down into rock; water 310 gallons per minute.

October 10.—Got squared down through rock, and at 5.30 P.M. started inside cribbing and puddling from bottom; in this and the following shaft the inner cribbing was of 2-inch by 12-inch timber, laid flat; the space between the outer and inner cribbing was 10 inches, which was filled with the puddling; water 310 gallons per minute; sunk during past four days 3 feet through limestone, practically finishing the difficult part of the shaft. Depth, 173 feet.

October 11 to 25.—Occupied in building up inside cribbing and puddling between; water being allowed to fill up behind.

October 25.—Tore down old top works and started permanent tower.

November 5.—Started to pump the shaft out.

November 10.—Got water out, but found puddling was not a success; the difficulty had been in getting it packed under running streams; caulking was now tried without effect, the shaft making 200 gallons of water per minute.

Nevertheless, sinking was resumed November 12th, and steadily progressed through the solid rock till coal was reached, except for two delays of a week each, when endeavors were made to shut out the water. Flooring was put on, but to no effect. Then the experiment was made of pumping in cement between the inner and outer cribbing, a method notably successful in the Croton Aqueduct of New York city, to fill voids behind the brick lining; but here the conditions were such that it failed; the streams of water were too strong for the cement to set, and it washed out again.

After this no attempts were made to shut water out of the shaft, and except puddling, none in the later shafts. However, to keep the hoistways dry and also prevent the water from falling clear to the bottom of the shaft, water-rings were put in each shaft just below where the water enters, from which the water is piped to a pumping station on an upper seam. The water-rings are assisted in collecting the water by lining the shafts above them with flooring raised from the curbing by nailing on top of laths, thus keeping the water behind the flooring till it enters the ring.

Under the circumstances at Ladd, the writer believes this way is even better than if the shafts had been made water-tight. The water has so materially lessened since the first shafts were sunk as to cause belief that the bulk of it was held in the ground like an underground lake, and that this has now been drained, so that what is coming now is the seepage from the surface water-shed. The total quantity from the present three shafts averages this year (1894) about 135 gallons per minute. As the water is of excellent quality, it is used in the boiler plant and the town water system. While largely in excess of present needs, it will no doubt all be wanted in the future. Moreover, had the shafts been made

tight, there would be the constant menace of a large body of water liable to be let down on any rupture of the shaft, a thing unlikely and yet always feared. As it is, there is no pressure whatever from the water, the shafts draining freely the natural flow of the strata.

Before the shaft last described, now known as "A" shaft, had reached the coal, the sixth attempt or "B" shaft, was started on November 14, 1889, 50 feet west of the third attempt, now known as the air shaft, but which was temporarily abandoned at 125 feet. The latter shaft was now kept pumped out, materially helping in the sinking of "B" shaft, which made much less water than the previous shafts. Even when "B" shaft got below the third attempt there was not nearly so much water, for the ground seemed already largely drained after a year and a half of steady pumping. Accordingly "B" shaft was sunk much more rapidly than its predecessors. This was not entirely due to less water but partly to the experience gained by the sinkers in meeting the peculiar difficulties of the field and partly to the improvements made in the appliances. Among the latter was the plan of suspending the curbing from solid wooden triangles instead of the open Howe truss, which could not be designed to meet immensely varying strains, and so on several occasions had been crushed. Another improvement was in the shoe in making the plate braces so they could be easily removed on reaching the solid. They were made heavier but fewer in number, forming 12 compartments, instead of 15, as in "A" shaft. This shoe was highly satisfactory in all respects (see Figs. 3 and 4).

The only serious difficulty that "B" shaft encountered was when, at a depth of 50 feet, a hole came to the surface along side of the shaft at the east end, causing it to swing 6 inches out of plumb. The hole was promptly filled up with clay, which stopped the running, and no further trouble ensued. On December 31, 1889, the shoe was down on the solid rock.

The speed of sinking the fourth, fifth and sixth shafts is as follows:

Fourth Shaft.—Started January 8, 1889. Reached rock June 30, 1889, a period of 174 days. Of these, 96 days were lost in delays, 78 days only being spent in sinking. Depth of shaft to rock, 162 feet. Average progress per working day, composed of three 8-hour shifts, 2.1 feet. Maximum rate of pumping, 640 gallons per minute.

Fifth Shaft "A."—Started August 10, 1889. Reached rock October 6, 1889, 58 days total. of which 7 were lost in delays and 51 spent in sinking. Depth of shaft to rock, 170 feet. Average progress per working day, 3.3 feet. Maximum rate of pumping, 500 gallons per minute.

Sixth Shaft "B."—Started November 15, 1889. Reached rock December 31, 1889. Total, 47 days, of which but 2 were lost in delays; 45 were spent in sinking. Depth of shaft to rock, 160 feet. Average progress per working day, 3.6 feet. Maximum rate of pumping, 350 gallons per minute.

There was no detailed record kept of the third or air shaft, but after getting "B" shaft down, sinking was resumed from where it had stopped over a year before on account of the lightness of the shoe, and now that "B" shaft was draining the water there was no trouble in getting the air shaft down. Thus three of the original six attempts were finally successful; and all the shafts in which the shoe was used succeeded in reaching rock.

I will now give a description of the details of the shoe, method of hanging the curbing, etc., as finally developed and used in sinking "B" shaft.

Beginning at the top, there is first in order a platform of 2-inch plank laid on the surface about the shaft, and covering an area 30 by 46 feet; on top of these, running across them and parallel to the sides of the shaft are 60-pound steel rails. These form the foundation of the four solid wooden triangles which carry the weight of the curbing not sustained by the friction of the ground. Each triangle is made of 8 pieces of 12-inch by 12-inch timber, the bottom one 48 feet long, the next 4 feet shorter, and so on to the top one, which is 20 feet long. The triangles run across on top of the rails and the narrow way of the shaft. On them and across them rest two 16-inch by 16-inch timbers 20 feet long. These are nearly over the side walls of the shaft; through them pass the 8 rods which sustain the curbing, four to each side or timber, huge washers under each rod head distribute the strain over the timber, which in turn distributes it to the triangles. The whole forms an almost rigid structure, so that when subsidence comes, everything goes down at the same time. The hanging rods are steel, and made in 10-foot lengths, the ends upset or thickened so that screw-couplings are made without weakening. The upper lengths are 2½ inches in diameter, every three lengths down the size decreases ¼ of an inch, so that the bottom lengths are 1¼ inches in diame-

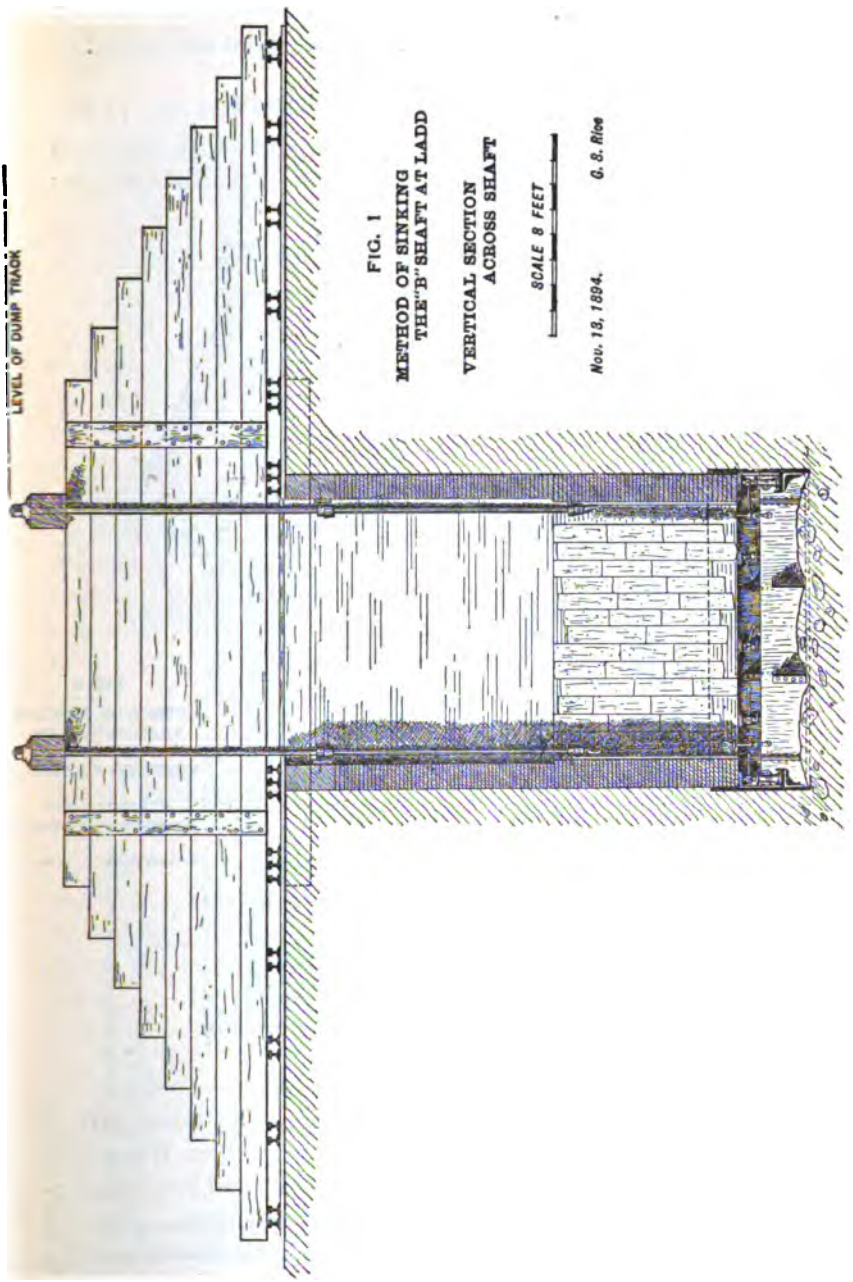


FIG. 1
METHOD OF SINKING
THE "B" SHAFT AT LADD

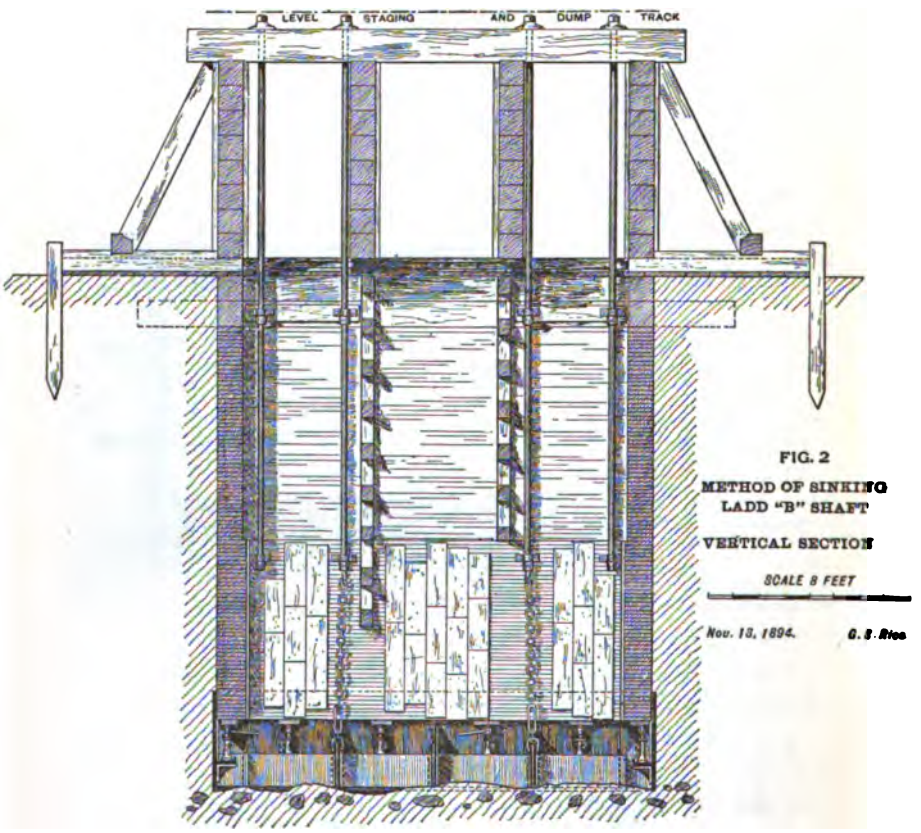
VERTICAL SECTION
ACROSS SHAFT

SCALE 8 FEET

Nov. 19, 1894. G. S. Rice

ter. The support to the curbing is, as finally adopted, an iron lug placed under the screw-coupling piece at each joint and spiked to the cribbing.

The shoe as finally designed and used in "B" shaft was 12 feet 8 inches by 17 feet 6 inches inside measure, built of ¾-inch steel plate, the sides 4 feet deep, of which the upper 16 inches was the



shield embracing the bottom of the curbing. The lower part of the shoe was divided into 12 compartments by three transverse braces of ¾-inch plate, doubled, 22 inches deep, and two longitudinal lines of braces, of ¾-inch plate, 16 inches deep. Around the inside of the shoe 12 inches from the bottom runs a shelf 9 inches wide of ¾-inch plate, braced below with brackets, and with a 2-inch ledge in front. This forms the press-plate on which are

placed the jack-screws to force down the shoe; directly above is

FIG. 3
PLAN OF FINISHED "B" SHAFT.

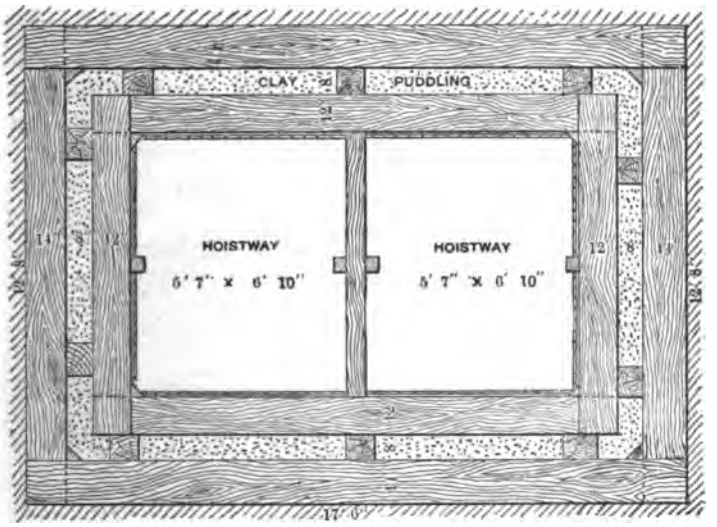
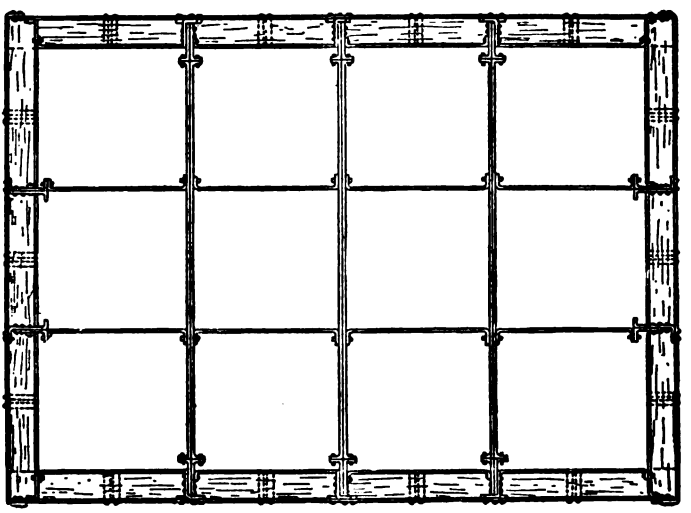


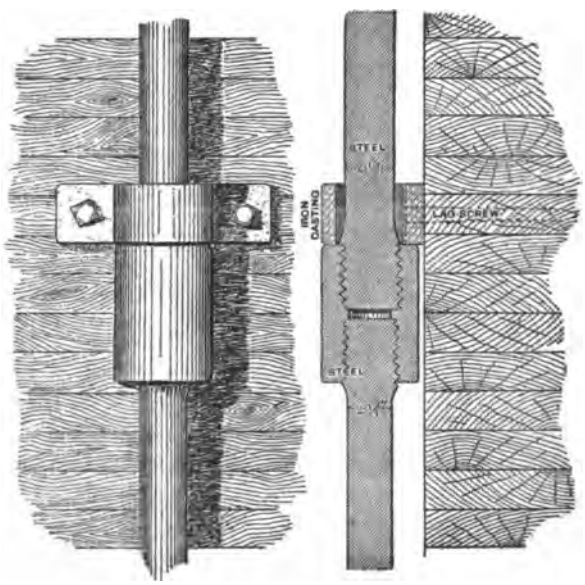
FIG. 4
GROUND PLAN OF SHOE.



the shaft-cribbing against which the jack-screws bear. Although

the shoe itself weighs 8 tons, the jacking was often very hard. The mode of operating is to apply the jack-screws till the shoe has been forced down from 2 to 10 inches, depending on the ground never more than 10 inches, which leaves but 6 inches of shield lapping the cribbing. Then the shoe is leveled carefully, the jack-screws removed, the 2 inch cribbing-plank put in place and spiked upward to the previous course. It is further tied, till the next hangers are put on, by boards nailed up and down the

FIG. 5 FIG. 6



DETAIL OF ROD COUPLING

curbing. The cribbing is arranged with butting-joints, the planks alternately overlapping, a simple and a very strong way with plank laid flat. It is further strengthened by triangular corner-strips.

Two-inch planks are used for the cribbing instead of thicker timber, because more easily handled in the cramped space at the bottom of the shaft, and they are little less strong for the same thickness of wall. After as many courses of cribbing are in as the space allows for, frequently in bad ground only one, the jack-screws are replaced and the operation repeated. Separate plate-covers were provided for the compartments of the shaft " B " shoe,

but it was found that the rushes of sand could be kept down if the excavation were not carried below the press-plates; and as the covers would hamper the work they were not used. They were kept at hand, however, the idea being, that when dangerous ground was expected, all the compartments except one or two would be closed.

Meantime the excavation and pumping goes on according to circumstances, and with the customary appliances.

To provide for supporting the shoes when a very soft spot is reached, chains, one in each corner, pass around the braces and hook to the hanging rods. An improved detail would be the insertion of a long turn-buckle at the lower end of each chain, fastened by clevis to a brace. At Ladd full weight was never thrown on the chains, the shoe always binding on some part; in soft ground, where there was danger of rushes, excavation was never advanced below the bottom of the shoe. There were usually three pumps hanging in the shaft, one in each compartment. The vertical Deane plunger pump with a 4-inch delivery was the favored type. The pumps were hung by hemp cables from capstans at the top, so as to be readily raised and lowered, the steam and water connections to the pipe lines being made with flexible hose.

In conclusion, I will say that I think this system of sinking shafts well fills the gap in deep shaft sinking, between the solid-ground systems and the true drop-shaft system. For instance, here at Ladd, the first failed in two hard pushed attempts, the second also failed after a shorter trial, but the boulders and hard ground met deeper, fully showed how impracticable it would have been. Of other known systems, the pneumatic is out of the question for over 70 or 80 feet of water-pressure, and while the Poetsch freezing system alone seems applicable to nearly all circumstances, its present great cost makes it prohibitive except in extraordinary cases. On this account, leaving the freezing system out of consideration, where there is a ground filled with water and over 80 feet in thickness to be pierced, too soft for solid ground systems and yet containing boulders, cemented material, or some hard ground which would prevent any kind of a drop-shaft, the method described in this paper is singularly well adapted.

CHLORIDE OF SILVER AS AN ANTI-FRICTION MATERIAL.

By MALVERN W. ILES, Ph.D.

It was recently discovered at these works that fused chloride of silver was a remarkably good non-conductor of heat; in fact, this substance possesses this property to such a striking degree, that the writer has conceived the idea it could be used satisfactorily as an anti-friction material upon a large number of machines running at a high velocity, such as upon many electrical machines, and many delicately adjusted machines and instruments.

If one takes a quantity of freshly precipitated chloride of silver, dries it, and then fuses it, and then casts the fused chloride into some small mould, he can then hold this substance up against an emery wheel running at an immense velocity without imparting an appreciable heat to the hand, thus readily demonstrating the property of chloride of silver being a wonderful non-conductor of heat.

This substance has properties which will eminently fit it for purposes similar to Babbit metal, as it can not only be cast like tin, lead, iron, and other metals, but also it can be turned in a lathe like any metal. Percy mentions the fact that snuff boxes have been made from it.

Berthier states chloride of silver has a melting point of 260° C., whilst Rodwell says its melting point is near 360° C. (See Percy on silver and gold, page 57).

Aside from using this substance in journal-boxes like Babbit metal, one could use the freshly precipitated chloride of silver as an emulsion suspended in oil.

The chief drawback would seem to be its cost; yet, doubtless, there are a vast number of places where this would cut but little figure, provided it did the work in a highly satisfactory manner, and one should not forget in this connection that silver can now be bought in large quantities at sixty cents per ounce, and if our narrow minded "gold bug" friends are to have their way much longer it may be cheaper yet.

As the Quarterly is a scientific periodical, and not a political organ, I will stop right here, believing that silver has been regarded as a noble metal for countless ages, and is likely so to remain for all time.

THE NEW CONDUIT OF THE ROCHESTER WATER WORKS.*

By E. KUICHLING.

Before entering upon the subject of this paper, it may perhaps be expedient to give a short account of the old water works of the city, and the circumstances which led to the necessity for an additional supply.

The question of providing a public water supply for the city had been considered for some years prior to 1860, at which time the population was about 48,000; but it never assumed definite form until that year, when a private corporation obtained a franchise for bringing water by gravity from Hemlock Lake, which is situated in a hilly district about 29 miles south of the city. This corporation, however, failed to accomplish its purpose after spending several hundred thousand dollars in the attempt; and as there was no evidence that the undertaking would ever be properly completed, the city finally resolved to build an entirely independent system of water works.

A Board of Water Commissioners was accordingly created in April, 1872, and on November 15th of the same year, this board reported in favor of a dual system of supply, selecting Hemlock Lake as the most expedient and desirable source for obtaining by gravity an abundance of pure, soft water for domestic and general uses, and supplementing the lack of efficiency of the gravity works, for fire purposes in the central and manufacturing districts of the city, by a separate direct pressure pumping system supplied with hard and impure water from the Genesee river, which flows northerly through the town.

The final plans for this project contemplated an ultimate capacity of about 7,000,000 gallons per day from each of the two systems, to be distributed through about 40 miles of pipe in the city streets; they also provided for the construction of two reservoirs on the line of the gravity conduit, one on the southern

* This paper is the substance of one of a course of lectures by prominent civil engineers before the engineering students of The School of Mines for the year 1894–5, given under the auspices of the Department of Civil Engineering.

boundary of the city for distributing purposes, and the other about nine miles south of the city for storage purposes. The total expenditure for the work was limited to $3,000,000.

The general plan thus outlined was duly approved by the municipal authorities, and early in 1873 the work was advertised for letting. Meanwhile the necessary details of the undertaking had been elaborated under the direction of the Chief Engineer, Mr. J. Nelson Tubbs, and construction was commenced soon after the contract was awarded. As it was anticipated that the long gravity conduit would require nearly three seasons to finish, the direct pressure system was completed first and put in full operation in February, 1874, with 7.32 miles of distributing mains. The gravity works, with the two reservoirs, a compound conduit consisting of 9.75 miles of 36-inch riveted wrought-iron pipe and 18.50 miles of 24-inch pipe, mainly of cast-iron, and 51.52 miles of distributing pipe, were finished early in 1876.

It may be remarked that when these works were planned, the city had a population of about 70,000, and an area of 4840 acres with 156 miles of streets and alleys. Few citizens then believed that the population would ever reach 120,000, and those who were bold enough to venture the opinion that this limit would ever be exceeded, were regarded as dreamers. It was pointed out that the proposed capacity of the gravity works would suffice to give 60 gallons of potable water per head per day to 120,000 people, and as not more than four-fifths of the population would probably ever become consumers of the water, the supply was thought to be adequate for a great many years. These estimates, it must be remembered, were made twenty-three years ago, when the fund of information regarding water supplies and the growth of cities was not only very much smaller than at present, but was also vastly more difficult of access. They were the outcome of many careful inquiries, and are therefore entitled to lenient criticism.

Soon after the completion of the works, however, the city boundaries were moved far outwards on all sides. A large suburban population was thus added and the municipal territory was increased to over 11,000 acres, with about 220 miles of streets. This was followed by a period of rapid development, so that Rochester has now an estimated population of 160,000, and an area of nearly 12,000 acres, with 295 miles of roadways, in which 255.72 miles of water distributing mains have been laid. Of this

aggregate length 237.27 miles belong to the Hemlock Lake system and 18.46 miles to the Holly system. Connected with these mains are 2482 hydrants, 2480 stop-valves and 27,228 taps or service pipes.

The capacity of the old conduit from Hemlock Lake to Rush Reservoir had been carefully gauged several times during the spring and summer of 1876, and found to be about 9,000,000 gallons per day, or 25 per cent. more than had originally been estimated. As a consequence of this large delivery, no restrictions in the use of water were enforced by the authorities up to 1885. In the meantime, the poor quality of the sub-soil water and the drainage of many private wells by sewerage works in almost every portion of the town had caused such a demand for the Hemlock Lake water, that the distributing system was rapidly extended, and soon almost every building in streets where water mains were laid was provided with a water service pipe. The consumption thus became much larger than had been estimated to occur so soon after the works were finished, and as large quantities were lost by defective house fittings and lavish use, it finally became necessary in 1886 to enforce measures for preventing waste as it was evident that the limit of the conduit's capacity would otherwise soon be reached.

With the continued fast growth of the city, however, these restrictive measures could not long be successful, and the limit was at last reached in 1888 when the population was about 125,000, with 190 miles of mains and 21,000 house connections from the Hemlock Lake system. In that year the storage in the reservoirs was nearly exhausted, and it was then definitely realized that the demands for the water were greater than the supply. Chief Engineer Tubbs was therefore authorized to make surveys and examinations for procuring an additional supply, and in September of the same year, he presented his report in which, after considering various remedies for the existing conditions and a few sources for the additional supply, he recommended the early construction of a new conduit with a capacity of 15,000,000 gallons per day, from Hemlock and Canadice Lakes.

The plans outlined in this report, however, did not appear to be generally accepted, and the matter was submitted on February 16, 1889, to the well-known engineers, Messrs. A. Fteley, of New York, and J. T. Fanning, of Minneapolis, Minn., for thorough investiga-

tion. Several new surveys were made under their direction, and on May 14, 1889, they reported in favor of either Hemlock Lake or Conesus Lake as a proper source, and that the new conduit should have a capacity of 15,000,000 gallons per day. While their plans differed in detail from those of Mr. Tubbs, they agreed with the latter as to source and required quantity.

No definite action upon these reports was taken by the municipal authorities, and the agitation of the subject was briskly continued by the promoters of other plans. Meanwhile it became evident that temporary relief would be needed, even if the construction of a new conduit to Hemlock Lake were authorized, since such an undertaking would require at least two years for its completion. A number of sources for temporary use were thoroughly examined in 1889, and early in 1890, but as they proved to be deficient, either in quantity or quality, the only resource left to prevent the depletion of the reservoirs was to make the consumption in the city equal to the delivery of the conduit, by suitably throttling for a portion of the day a few of the stop-valves in the principal mains at the foot of the hill on which the distributing reservoir is situated. This plan was accordingly adopted in June, 1890, and was retained with some modifications until August, 1894.

It should be remarked that up to June, 1890, it had been taken for granted that no appreciable diminution in the discharging capacity of the old conduit had occurred, and that it was still continuing to deliver about 9,000,000 gallons per day. At that time, however, a close gauging of its flow into the Rush reservoir was made, which revealed the fact that its actual delivery was then only about 6,730,000 gallons per day. The discrepancy between these two discharges could not be accounted for by leakage or abstraction of water from any portion of the conduit, and hence it was evident that its efficiency had become permanently impaired. Meanwhile, Chief Engineer Tubbs became ill and resigned his position at the end of July, 1890. A few weeks later the writer, who had severed his connection with the Water Works Department some years previously and was engaged elsewhere, was appointed to take charge of the works.

In this state of affairs, the matter of obtaining a temporary additional supply of potable water was considered of chief importance. Some months previously an old artesian well in the town of Gates, about one mile west of the city, gave promise of furnishing a sup-

ply of 1,000,000 gallons per day, and contracts had been made for the rental of this well, and also for the delivery of a suitable pumping engine and the necessary quantity of pipe, for the purpose of forcing this water directly into the nearest city distributing pipe. The machinery had, however, not yet arrived, and as some doubts regarding the permanency of the flow from the well had been entertained, preparations were made to test its capacity in a time of drought. The result of this test was very discouraging, and as the owner of the well refused to allow any new wells to be drilled anywhere on his land, also because the geological characteristics of the region were unfavorable to the assumption that the same vein of water could be tapped by other wells at some distance from the original one, it was deemed prudent to investigate other sources before incurring the large expense involved by the construction of the above described temporary works, especially as it was very doubtful whether the well would yield even 500,000 gallons per day during dry periods.

To complete our outline of this part of the subject, it may also be mentioned that none of the various propositions for temporary relief, which were advanced after the failure of the Gates well, met with approval until March, 1893, when an agreement was made with a private company whereby a large quantity of water was to be delivered by them, at very reasonable rates, into the distributing reservoir from a series of wells which they proposed sinking in the flats about one mile south of said reservoir. This source had been discovered by the company a short time previously, and full control of the land for a considerable distance around their experimental wells had been secured by them.

As no other arrangements for the use of this water could be made, the company accordingly caused six 10-inch wells to be drilled and equipped with suitable pumps, and a 16-inch cast-iron force-main about 5000 feet in length to be laid to the reservoir. The first delivery of water was made on June 12, 1893, at the rate of only about 500,000 gallons per day, and although every effort was made to increase the yield of the wells, no appreciable improvement occurred thereafter. This was a serious disappointment both to the company and to the public, since the volume thus delivered was by no means adequate to enable the Water Department to dispense entirely with the obnoxious system of balancing inflow and outflow from the reservoir. As this quantity, how-

ever, afforded a little relief, the use of the water was continued until October, 1894.

Early in October, 1890, the writer was requested to investigate the various general plans for a permanent additional water supply which had previously been submitted by the other engineers above mentioned, and to make such further examinations for the same purpose as he might deem necessary. This work was soon undertaken, and on December 16 and 30, 1890, reports and estimates were presented for permanent works from Hemlock Lake, Conesus Lake and Lake Ontario on somewhat different plans from the others. These documents also exhibited a comparison of all the various estimates which had been made up to this time for new works from the same three sources, and it was seen therefrom that the choice lay between Conesus and Hemlock Lake, both on the score of quality of water and cost of construction.

A brief description of the three sources to which reference has been made in the foregoing may now be given. Hemlock Lake is a beautiful body of water about 6.6 miles long, and 0.6 miles wide. It is situated in a hilly region, about 29 miles south of Rochester, and lies about 386 feet above the general level of the city. Its area at ordinary low water is 1828 acres, and its average depth in the middle is 65 feet. Including the water surface, its drainage area is 27,554 acres, or 43.05 square miles, a large proportion of which is steep, and covered with forest. The only settlement of considerable size on the watershed is the village of Springwater, which is located nearly three miles south of the head of the lake, and has a population of about 600. On the rest of the area the resident population is probably about 1000.

Canadice Lake lies about two miles east of Hemlock Lake, and is 200 feet higher than the latter. It is about 3.13 miles long, 0.33 mile wide, and its average depth in the middle is 70 feet. At ordinary low water it covers an area of 648 acres, and the total drainage area is 8883 acres, or 13.88 square miles. This territory is occupied wholly by farms and woods, with a population of not more than 400. The stream which forms the outlet of Canadice lake must also be considered in this connection, as it unites with the outlet of Hemlock Lake at a point about one-third of a mile below the foot of the latter lake, and a drainage area of 3525 acres, or 5.49 square miles. The character of this territory is similar to the other watersheds, and its population is about 200.

It should also be noted that for nearly one mile below the foot of Hemlock Lake, the ground is nearly level along the course of the outlet, but rises with easy grades to the base of the hills which form the sides of the valley. With such a configuration of the surface, it is obvious that the flow from Canadice Lake and its outlet can readily be diverted into Hemlock Lake, either by means of a new open or closed channel, or by a low movable weir placed across the channel of the Hemlock outlet below its junction with the Canadice outlet. In this manner Hemlock Lake can be made the general reservoir for the yield of the three distinct watersheds already considered, whose aggregate area amounts to 39,952 acres, or 62.43 square miles.

Conesus Lake lies parallel to, and a few miles west of, Hemlock Lake. It is about 7.8 miles long, 0.63 mile wide, and has an average depth of 45 feet in the middle. At ordinary low water, its area is 3184 acres, and its elevation is about 308 feet above the general level of the city, or 78 feet lower than Hemlock Lake. Including the water surface, its drainage area is 39,980 acres, or 62.47 square miles, and is, therefore, practically the same in extent as that of Hemlock and Canadice lakes and Canadice outlet combined. The character of the territory, however, differs from that of the latter by having a much larger proportion of open farming land, less abrupt hillsides, and a greater average density of population. Several good-sized villages, as well as a few smaller settlements, are on the watershed, and from the recent census statistics it may be estimated that the total number of persons residing thereon permanently is at least 3500. This lake entends a few miles further north than Hemlock Lake, but from the preliminary surveys it is found that the length of a practicable route for a conduit to Rush reservoir is only 2.6 miles shorter than one from Hemlock Lake.

Lake Ontario is about seven miles directly north of Rochester, but its average water surface is 266 feet below the general level of the city, and 390 feet below that of Mt. Hope reservoir. To avoid the influence of the oily and sewage-polluted water of the Genesee river, the intake of a conduit for supplying the city must necessarily be located as far distant from the river as possible. As the prevalent winds are from the west and northwest, and from the peculiar configuration of the lake shore, it is obvious that no suitable location for an intake can be found at any reasonable distance

easterly from the mouth of the river, and hence such a location must be sought to the west thereof. For some miles in this direction, however, a series of swampy bays or ponds, connecting with the lake, are encountered, whose waters are entirely unfit for domestic use, both by reason of excessive aquatic vegetation, and from the fact that they are contaminated by the drainage from nearly the whole of the northwestern quarter of Monroe county. This area is relatively thickly populated, and contains a large number of villages and hamlets. In view of all these circumstances, the nearest available location for an intake on the lake shore is at a point about 8.5 miles west of the mouth of the river, and 15 miles in a direct line northwestwardly from Mt. Hope reservoir. By the shortest practicable route, without crossing the populous districts of the city, this distance would become about 17 miles.

Briefly summarized, the various reports and estimates showed that the long force main, costly intake works and pumping engines, and the capitalization of the annual expense for lifting the water to so high an elevation, would render the Lake Ontario project far more expensive than either of the other two; and that while a conduit from Conesus Lake might cost a little less than one from Hemlock Lake, yet the expense of protecting the water from pollution, by introducing and maintaining adequate sanitary arrangements on the large and relatively populous watershed of Conesus Lake, would probably more than make up the difference. Various other elements also entered into the choice between these sources, but after due consideration, the preference was finally given to Hemlock Lake by all the municipal authorities on June 16, 1891.

Pending this definite action, a bill was introduced in the Legislature early in 1891, whereby the city would be allowed to take an additional water supply from either Hemlock or Conesus Lake, and to bond itself for the necessary costs in the sum of $1,750,000. For some reason, however, the measure was opposed, and the Legislature adjourned before the bill could be passed. As a large amount of engineering work, both in the field and the office, was necessary before the details of any of the general plans could be prepared, and no funds for the purpose being available, the Common Council appropriated an adequate sum on June 26, 1891.

Soon afterward two surveying parties commenced operations and were kept busy during the remainder of the year examining

various routes and preparing topographical maps thereof. From the data thus acquired, careful studies and comparative estimates of the most feasible routes were then made, and a definite location of the conduit established. The previous hydrological investigations were also thoroughly revised for the purpose of determining the storage volume needed in the lake during a cycle of years of least observed rainfall, and from this the necessary depth of the upper end of the conduit below the existing ordinary low-water level of the lake was fixed. Nearly a year was occupied in this work and the preparation of the drawings and specifications.

A new bill similar to the one above mentioned was introduced in the Legislature early in 1892, and succeeded in becoming a law on April 20, 1892. Work on the new conduit plans was therefore continued energetically, and proceedings were at once instituted to obtain the necessary rights of way in those localities where the route had been fixed.

The plans for the new conduit, as finally adopted, contemplated the construction of a brick conduit, of horse-shoe shaped cross-section, about six feet in diameter, on a grade of one in 4000 from the northeastern corner of Hemlock Lake to a point on the east bank of the creek about 12,000 feet northerly. Of this length, 7500 feet was in tunnel worked from several shafts through the clay and shale rock which underlies the region, while the remainder was in open excavation. A large and deep gate and screen house was to be built at the shore, from which a steel intake pipe, 5 feet in diameter, and 1600 feet long, was to be extended into the lake to a point where the water was about 35 feet deep. The pipe was to be laid in a channel dredged to a depth of about 19 feet below the existing ordinary low-water level of the lake until this depth of water was reached, after which it would be laid directly on the bottom, and terminate in a submerged timber crib resting on the bottom. At its beginning in the gate house, the invert of the brick conduit was to be about 17 feet below the aforesaid low-water level; and at the northerly terminus it was to be a little above the average water surface in the creek, in order to provide for natural drainage in case of cleaning or repair. To prevent the masonry of the conduit from being injured by the water pressure which would ensue from improper manipulation of the works, an overflow chamber was to be constructed at the north end, whereby

the water surface in the conduit would effectually be prevented from reaching the top of the arch.

From the said overflow chamber onward to the storage and distributing reservoirs, the water was to be conducted in either a 36-inch cast-iron, or a 38-inch steel pipe conduit, laid on a continuous hydraulic grade to its terminus at the latter reservoir. This grade was about one in 570 for the total distance of nearly 140,000 feet, or 26.5 miles. The route was along the east side of the relatively narrow outlet valley with steep banks for a distance of about 2.0 miles to Richmond mills; thence northerly for about 3.5 miles across the undulating territory west of Honeoye Creek to a point where the valley again becomes narrow with high banks; thence still northerly a similar distance through the said valley, in which the creek meanders from side to side, the pipe crossing and recrossing the same nine times to avoid tunneling and location on treacherous banks; thence rising on the east side of the valley to the elevated plateau below the village of West Bloomfield, and continuing northerly along this plateau and across the deep depression called Surrine Hollow, for a distance of 5.35 miles; thence northwesterly along a highway and across fields for 3.41 miles in a direct line to Rush reservoir; thence northerly along the route of the old conduit and through the Henrietta road for 4.81 miles to a point where the prolongation of Pinnacle Avenue intersects said road; thence along said prolongation to and through Pinnacle Avenue for 3.31 miles to a point 439 feet north of Elmwood Avenue; and thence northwesterly across private and park lands for 0.69 mile to the east end of Mt. Hope reservoir. New gate houses and inlet works were also projected at both reservoirs.

It should be stated that the Pinnacle Avenue route was chosen, because it was foreseen that a new and large distributing reservoir would soon be required; and as the most available site for such a structure is on the elevation known as Cobb's Hill, at the southeastern corner of the city, while Pinnacle Avenue is nearly midway between this site and Mt. Hope reservoir, it follows that the said location of the pipe conduit would best serve both places. A few words, also, as to the reason for providing so large a masonry conduit and intake works at Hemlock Lake may be given. The enormous difficulties with quicksand which were encountered in the construction of the old conduit in this locality, and the discovery of extensive deposits of this material by preliminary borings

along several contemplated routes for the new conduit, indicated that the costs of construction for the latter would be so great, that the addition of 1.5 or 2.0 feet to the diameter needed for a discharge of 15,000,000 gallons per day, would not make a serious increase in the amount; and as this additional size would give the conduit a capacity for delivering easily about 32,000,000 gallons per day, which was the computed average yield of the entire watershed of Hemlock and Canadice lakes, it was deemed prudent to adopt the larger dimensions in order that no further outlay in this locality would arise, if a second additional water supply should be required in the future. The same considerations are also applicable with even greater force in the case of tunnel work, owing to the necessity of having room enough for the workmen to perform their labor properly and quickly.

Bids were requested from contractors for the masonry conduit work and the pipe work separately; the latter in turn embracing bids for both steel and cast-iron pipe, and for two different routes, designated A and B, for a portion of the distance.

It should be mentioned that route A, for the pipe conduit was located in the alluvial flats through which Honeoye Creek meanders, and involved several difficult crossings of the existing and former channels of said creek; while route B avoided some of these crossings by following the course of a certain lateral valley for some distance, and then returning to the main valley by means of a masonry conduit and tunnel about 1000 feet long. These two routes were each about 8000 feet in length, and formed a part of the entire length of 140,000 feet of conduit to be constructed in either case.

The lowest bid for the masonry conduit and tunnel work was made by William H. Jones & Sons, of Rochester, N. Y., its aggregate amount, as computed from the prices and estimated quantities, being $292,518; that for the pipe conduit was made by the Moffett, Hodgkins & Clarke Company, of New York City, their bids amounting to $903,324 with 38-inch steel pipe, by route A, and to $857,552.50 by route B. For the same work, with 36-inch cast-iron pipe as an alternative, the only bidders were Whitmore, Rauber & Vicinus, of this city, and a syndicate of cast-iron pipe manufacturers respectively, their joint bids amounting to $1,173,110 by route A, and $1,177,035 by route B.

From the foregoing bids it was seen that by route A the cost of

the new conduit with 36-inch cast-iron pipe would be about 29.9 per cent. greater than with 38-inch riveted steel pipe, and about 37.3 per cent. greater by route B. Much surprise was caused by this result, as well as by the entire absence of competition on the part of manufacturers of cast-iron pipe. It may also be remarked that the delivering capacities of the two kinds and sizes of pipe just mentioned were regarded as equal.

Before the work was definitely awarded, inquiries were made of several manufacturers of large cast-iron pipe whether any lower bids for such material would probably be received in case this part of the work were readvertised for letting. The replies were all to the effect that no reduction of prices could reasonably be expected which would make the cost of the work with cast-iron pipe nearly as low as that which would result by adopting the steel pipe; and as it was desirable that no further delays in commencing the work should occur, the decision was reached to construct the pipes of steel plates riveted together and properly protected from corrosion by an asphaltic coating. This decision was also influenced in large degree by many satisfactory reports as to the durability of such pipes in other localities, as well as by the good condition in which the old wrought-iron pipe conduit was found on its recent complete exposure for distances of several hundred feet at the crossings of the Lehigh Valley and Honeoye Valley railroads.

The contract for the construction of the masonry conduit and its appurtenances, which is designated as Contract No. 1, was duly awarded to William H. Jones & Sons on January 6, 1893; and on January 12th the award of Contract No. 2, for the construction of the 38-inch riveted steel pipe conduit, and all the required appurtenances thereto, was made to the Moffett, Hodgkins & Clarke Company. The proposals of these two firms were accompanied by thoroughly good bonds in the amount of $30,000 and $90,000 respectively, conditioned that they would accept the contracts if the same were awarded to them, and hence there was every reason to anticipate that the documents would be executed promptly. The award was accepted by Jones & Sons, but was declined by the other firm on the ground of an error in their figures.

This action of the Moffett, Hodgkins & Clarke Company involved the forfeiture of their said bond for $90,000, and, to avoid this great loss, they quickly obtained from the United States Cir-

cuit Court a temporary injunction restraining the Executive Board of this city from declaring them in default and proceeding with the collection of the money. Several attempts have since been made by the city attorney to bring the case to trial, but in every instance a postponement was secured by the opposing counsel. The case is of great importance to the city, and it is hoped that a settlement will soon be reached.

It was evident, from the legal procedure referred to, that great delay would result before the said company could be compelled by the court either to abide by its bid, or submit to the forfeiture of its bond; and as such delay would be prejudicial to the sanitary condition of the city, Contract No. 2 was awarded on January 20, 1893, to the next lowest bidder, which was the firm of Whitmore, Rauber & Vicinus, of this city. The award was made on the basis of using 38-inch steel pipe with route A, and was promptly accepted. The amount of the proposal, as computed from the prices and estimated quantities, was $1,123,920.

Early in March, 1893, both contractors for the new conduit commenced active operations on the lines of their respective work, the few preceding weeks having been fully occupied with making the necessary preparations. Arrangements for the speedy manufacture of the steel pipes were then also concluded by Whitmore, Rauber & Vicinus, the work being divided equally between the East Jersey Pipe Works, of Paterson, N. J., and the Rochester Bridge and Iron Works, of this city. The most improved machinery and appliances for the purpose were placed in both of these establishments, and the manufacture of pipe began as soon as the steel plates arrived from the rolling-mills. For the first-named works, the plates were made by the Carnegie Steel Company at Homestead, Pa., and for the second by the Paxton Rolling-Mill at Harrisburg, Pa. At each mill every plate was carefully examined by a competent inspector, and frequent tests of the quality of the material were made, as provided in the specifications. A check on this part of the work was also constantly exercised by independent tests made in other laboratories, as well as by the city's inspector at the pipe shops, so that every possible care was taken to secure good and sound plates.

The contracts provided that the steel should be of the class termed "soft," and be made by the open hearth process. Chemical analyses of each melt were required to show that the metal con-

tained not more than 0.60 per cent. of manganese, and 0.06 per cent. each of phosphorus and sulphur; while the physical tests called for a tensile strength of between 55,000 and 66,000 pounds per square inch, with an elastic limit of not less than 30,000 pounds per square inch, and an elongation of 22.5 per cent. in a length of 8 inches; also for various proofs as to cold bending, punching, drifting, and forging. Similar requirements were likewise made for the iron and steel rivets. The thickness of every plate was determined by fine micrometer measurements around the edges, and all plates which were less than 95 per cent. of the required thickness at any point were rejected without appeal; furthermore, at least 90 per cent. of the accepted plates were of full thickness at all points. Every precaution was also taken to prevent the formation of rust upon the metal, and to this end it was constantly kept under cover, from the time of its manufacture at the rolling mill, until the completed pipe was thoroughly coated in the pipe shop with a durable asphaltic varnish. In case of any accidental rusting, the plate was either rejected, or the rust was entirely removed by manual labor.

It was contemplated that the pipe conduit should be a continuous riveted tube throughout its whole length, without expansion joints or other mechanical devices for compensating changes in length caused by variations in temperature. By this continuity, such changes are prevented from manifesting themselves, and are replaced by internal stresses in the metal, which are far within its elastic limit for the range of temperature encountered in the work; but it becomes essential in this case that the strength of the net section of the plate at the circular seams shall be equal to the shearing resistance of the rivets therein. The joints were, therefore, carefully designed to meet this condition, and at the ends of the conduit, motion was prevented by bedding the pipe in large masses of masonry. Similar precautions were also observed in the design of all stop-valves and branches which were inserted in the pipe line. All of these appurtenances were provided with flanges and bodies of considerably greater strength than the pipe, and were connected thereto by numerous heavy bolts.

Great care was taken to make accurate maps and profiles of the route on a large scale. Upon these the pipe was carefully drawn, and every deviation from a straight line clearly indicated, after which they were handed to the manufacturer. As it was required

that the pipe should be made so as to bring all the straight seams in the upper quarter of the circumference, close attention to the work on his part was imperative, and a good check on the computations made by the engineering force was thus secured. In manufacturing the plates into pipe, the utmost care and precision in edging, punching, riveting, and calking were used. One-half of the whole number was rolled into truly cylindrical "outside" sections or courses, and the other half into similar "inside" courses, which fitted closely into and alternated with the former. The internal diameter of every inside course was made exactly 38 inches throughout, and the net length of both kinds of courses, estimated from the centres of the rivet holes at the ends, ranged from 6.83 to 6.75 feet, according to the thickness of the plates. Each course or section, moreover, was made of a single sheet, of such width as to form the required cylinder with ample allowance for overlap.

Four classes of pipe, formed of three different thicknesses of plate, were manufactured and arranged according to the water pressure to which they would be subjected in the line of the conduit. For pressure due to static heads of 120 feet or less, the pipe was made of plates ¼-inch thick, with the longitudinal or straight seams single riveted; for heads ranging from 120 to 153 feet, the same thickness was used, but the straight seams were double riveted; for heads between 153 and 199 feet, the thickness was $\frac{5}{16}$ inch, and for heads between 199 and 263 feet, the thickness was ⅜-inch, with the straight seams double riveted in both classes. All of the circular or round seams were single riveted, except where two different classes of pipe were joined together, in which case these seams in the thinner pipe, including the junction seam, were double riveted for a distance of about 200 feet. The object of this provision was to make the efficiency of the double riveted round seams in the thinner pipe approximately equal to that of the single riveted round seams in the thicker pipe, as it was computed that in the distance mentioned, the friction of the earth against the pipe after the trench is properly refilled, would be sufficient to balance the resultant of the longitudinal forces produced in the two classes of pipe by the assumed extreme variation of temperature in the finished conduit, which was here taken at 45° F. Each class of pipe is, therefore, regarded as being firmly anchored in the soil, except for the said distance at the junctions.

The pipe was generally furnished in lengths of about 27⅓ feet,

consisting of four courses riveted together in the shop with powerful machines, and having all seams thoroughly calked on both the inside and the outside. Changes of direction, either in alignment or grade, were made by slightly bevelling, at one end only, as many courses as were needed to make the required curve or deflection. These bevelled pieces were then power-riveted in the shop, either to each other or to square-ended courses, according to whether the curve was of short or long radius. In the former case it was found expedient to rivet only two courses together in the shop, on account of difficulties in the transportation of longer pieces; but for easy curves requiring only one bevelled course to three square-ended ones, four courses were riveted together, the same as for straight pipe. To avoid multiplicity of patterns, a standard bevel, of 2 degrees and 43¼ minutes, corresponding to an offset of 1.806 inches in the diameter of 38 inches, was adopted and used as far as possible throughout the work. With this deflection it was still practicable to make a good circular seam without "flanging" or hammering over the ends of the courses. If a somewhat smaller angle was needed occasionally, a special pattern, therefor, was made; and deflections of less than one-third degree were easily accomplished by slightly reaming out the rivet holes on opposite sides in the round seams.

The above-mentioned standard bevel on the end of every fourth course forms a regular polygon which fits closely what railroad engineers designate a 10-degree curve; applied on the end of every second course, it corresponds to a 20-degree, 8-minute curve, and on the end of every course, it gives a 41-degree, 9¾-minute curve. These three curves may also be defined in terms of their radii, which are 573.7, 286.1 and 142.2 feet respectively; and all changes in direction and grade of the pipe conduit were made in accordance therewith. It may also be remarked that the work was in general so arranged as to avoid making a change of grade in a curve, although in a few instances such a combination could not be obviated without incurring large additional expense for excavation.

As soon as practicable after the riveting and calking on a pipe was finished, it was thoroughly cleaned, heated in an oven to about 300° F., and then placed in a large tank containing the hot coating mixture, where it was allowed to remain for such time as would suffice for the temperature of the metal to become the same as that

of the mixture. The pipe was then removed from the bath and the surplus coating substance allowed to drip off, after which its treatment by the two different manufacturers varied very materially. At the East Jersey Pipe Works a purely asphaltic coating was used, which became hard when cold; and hence after having been dipped the pipes were simply placed on skids outside, where the material was left to harden. At the Rochester Bridge and Iron Works, on the other hand, a species of japan coating was used, which required the pipe to be placed vertically in a large brick oven after dipping, and baked therein at a high temperature for about ten hours on an average.

Much attention was given to the matter of preparing and applying a coating mixture which should be durable, hard, tough, and adhesive to the smooth surface of the steel plates at all ordinary temperatures. Numerous experiments with different kinds of asphalt and other substances had been made by the writer at intervals during several years before the new conduit was projected, in the hope of finding a compound which would meet all of these requirements; but as they were generally more or less unsatisfactory in fulfilling the last named condition, it was deemed expedient after the decision to use steel pipe in the new work was reached, to seek counsel from some chemist who had made the preparation of paints, varnishes and lacquers a special study. In response to various inquiries, the writer was referred to Prof. A. H. Sabin, of the well-known firm of Edward Smith & Co., varnish manufacturers, of New York, and finally succeeded in persuading him to undertake the necessary investigations. Much time, however, was required for this purpose; and as the East Jersey Pipe Works was soon ready to commence making pipe, the proprietors were directed to use meanwhile the same asphalt coating which had been found to be very successful on numerous conduits in California, as well as on the large steel conduit recently completed for the water supply of Newark, N. J. This material had been highly commended by several distinguished chemists, and it was generally regarded as superior to any other preparation of asphalt which had yet been devised.

Every effort was made to obtain materials of the best quality for the purpose from California, also to prepare and apply the coating in the most approved manner. The results at first appeared to be very gratifying, but after the pipes had been exposed to the

air for several weeks, it was noticed that the high gloss of this coating gradually disappeared, thus leading to the inference that the substance was undergoing a slow change. In water, on the other hand, no alteration was detected, and it was therefore believed that the coating would prove serviceable after the pipes were once filled. It also failed in adhering tightly to the metal, and the contractors were subjected to great expense in painting with costly material large areas from which the coating had scaled off during transportation and handling. Directions were then given to substitute for the California asphalt, a mixture of refined Trinidad asphalt and the best grade of coal tar, thereby producing the same coating as had been applied to the old conduit, and which has proved to be durable at all events. Although this mixture was, on the whole, more satisfactory than the other one, it nevertheless left much to be desired in the way of toughness and adhesion to the steel.

Meanwhile the experiments of Prof. Sabin, in the direction of obtaining a better practicable coating, had resulted in the evolution of a japanning process which, from both theoretical and practical considerations, gave promise of conspicuous success. Pieces of small pipe, which he had coated in his laboratory, were subjected to numerous tests for determining the durability of the coating; and as it withstood all these tests perfectly, and, moreover, adhered remarkably well to the metal, its use for the remainder of the conduit was decided upon. At this time, however, the East Jersey Pipe Works had nearly completed their portion of the work, while the Rochester Bridge and Iron Works was just commencing operations on the pipe. The proprietor of the latter was accordingly requested to investigate the Sabin process thoroughly, and to adopt it if no valid objections could be raised against it by the expert chemists he was to employ for the purpose. As no such objections were forthcoming and nothing better was available, he promptly constructed the necessary expensive plant for carrying out the process under Prof. Sabin's direction, and coated all of his pipe in this manner. So far as can now be determined, this coating is superior in all respects to those which were applied to the first half of the conduit, and it is hoped that the crucial test of time will fully confirm this opinion.

Great care was also required in the handling and transportation of the pipes, both by railway and by wagon, to avoid damaging

the coating. To this end, all chains and bolsters or saddles which came in contact with the pipe were covered with old rubber hose, canvas or carpeting, and the site where each pipe was deposited, preparatory to excavating the trench, was thoroughly cleared of stones. In spite of these precautions, the abrasion of the coating in spots was unavoidable, not only from the processes of transportation, but also from the subsequent processes of riveting the pipes together. It may also be mentioned that during the latter work, canvas coverings or mats were placed on the top of the pipe outside, and on the bottom inside, wherever the workmen were engaged; and all who entered the pipe for any reason were required to use soft felt or rubber overshoes. As it was essential that every defective place in the coating should be repaired as well as possible, the use of a suitable asphaltic paint was necessary; and in the absence of anything better, a preparation called "P & B Paint" was selected for the purpose. This material consists of refined asphalt dissolved in bisulphide of carbon; and as the latter is a very volatile liquid, its rapid evaporation soon leaves a thick coating of hard asphalt on the metal.

The offensive odor of this liquid, however, is a serious objection to its use on the interior of the pipe, as the vapor is both suffocating and inflammable; hence it was necessary to insure the thorough ventilation of the conduit during its construction. For this purpose, as well as to afford future ingress for examination and repair, manholes with tightly fitting covers were riveted upon the pipe at intervals of about 1000 feet. The covers of two or three consecutive openings were removed while the interior of the conduit was being examined, and newly driven rivets and abrasions in the coating were being painted, and a strong current of air was forced through these portions of the pipe by means of a suitable fan or blower. In this manner the performance of the necessary inside painting work and its thorough inspection was made endurable.

It should also be stated that after the pipes had been delivered along the route of the conduit, two lengths were riveted together upon the surface of the ground, thus forming a section about 54.5 feet in length, and weighing from 7000 to 10,500 pounds, according to the class. These sections were then rolled in succession by a large number of men upon suitable timbers placed across the trench, where one or two strong derricks raised them clear of the

timbers and lowered them safely to the bottom of the excavation. One end of a section was then carefully fitted into the pipe which had previously been laid, and was temporarily fastened thereto with a number of bolts passed through the rivet holes. The exact adjustment of the section to its proper alignment and grade was then done, and after the rivet holes had all been made to coincide, either by reaming or a slight turning of the pipe, the joint was ready for the riveters.

Meanwhile the trench had been excavated truly to line and grade, and, wherever the soil permitted, its bottom was shaped to fit the convex exterior of the pipe. All large stones and boulders were carefully removed therefrom, and in rock excavation the trench was made somewhat deeper and then refilled to grade with earth. Where the bottom could not be shaped as aforesaid, wooden saddle-blocks were placed at frequent intervals and brought to grade by tamping the soil underneath. At the joints the trench was enlarged somewhat, so as to admit of inserting the hot rivets from the bottom and sides, the upsetting and hammering of these rivets being done on the inside of the pipe. The remainder of the rivets were passed into the pipe through a small hole cut in its top, and were upset on the outside whilst being held in place with a lever on the inside. On the completion of the riveting, the pass-hole was closed with a brass plug firmly screwed into place. These holes also served to assist in ventilating the pipe, as well as to facilitate the introduction of fresh supplies of paint to the workmen inside.

In refilling the trench, only the finest selected earth material was deposited under and around the pipe up to a level of six inches above its top, and was thoroughly rammed in thin layers as it was being thrown in, so as to give the pipe a solid bearing for its entire length. Somewhat less care was taken with the filling of the remainder of the trench, although the material was also compacted by ramming where required. For the greater part of the route, it became necessary to partially refill the trench soon after the pipe had been riveted together, in order to prevent the latter from floating in case that the excavation should accidentally be filled with water; but wherever practicable, a space was left open around every field-made joint, in order that any leakage might easily be discovered and remedied on the application of the water-pressure test to the conduit. On the other hand, in places

where no appreciable inflow of water could occur, the upper part of the pipe was left entirely exposed until after said test, thereby obtaining an opportunity for observing the quality of the shop-made seams.

Upon the completion of lengths of a mile or more of the conduit, each such section was in its turn thoroughly cleaned out and examined to see that all defects in the coating had been made good with paint, whereupon the ends were tightly closed up, either temporarily with a steel boiler head or permanently with a stop-valve, and the pipe filled with water from a force pump. The water-pressure was gradually raised until it became about 50 per cent. greater than that to which the conduit would afterward be subjected in its normal operation; and while under this pressure the work was closely examined for leakage. By this means all defects quickly manifested themselves and were thereupon promptly repaired. It may also be mentioned that the force pump was usually stationed at the beginning of the pipe conduit near the village of Hemlock Lake, and hence most of the sections above Rush Reservoir were thus subjected repeatedly to this severe test. For the portion of the conduit from Rush to Mt. Hope Reservoir, the force pump was not needed, as the static head from the said beginning of the work was amply sufficient for testing purposes.

A comparatively novel feature of the pipe conduit is the provision of a device, midway in the long stretch of 17.5 miles from its commencement to Rush Reservoir, whereby the pressures in the upper half will, under ordinary conditions of operating the works, always be limited to those due to the hydraulic gradient; while the maximum pressures in the lower half, which will result if the inlet valve to said reservoir be closed, will be about 26 pounds per square inch less than those due to the entire available head. The device consists simply of a short stand-pipe, rising from the conduit on the top of a hill up to the hydraulic grade line for Rush Reservoir, and communicating with an adjacent pipe which is continued down the hillside to the creek. With the flow properly regulated by the gates at the lake, and free discharge into said reservoir, the water will not rise in the stand-pipe quite up to the level of the overflow, and hence no waste will ensue; but if the discharge at Rush is stopped in some emergency, the overflow will at once come into action and carry the entire flow safely into the creek, thereby preventing the head on the upper half of the

line from acting on the lower half. The resulting loss of water from the lake will be trifling, as word can soon be sent to the latter place to stop the supply. On the other hand, the benefit derived from the device is the ability to use thinner plates for the pipe over a long distance, and thereby materially diminish the cost of the work.

At every summit on the conduit line, an air-valve of peculiar construction has been placed. The function of these appurtenances is both to afford a facility for letting out the air which may be confined in the pipe before it is filled with water, and to allow air in abundance to enter automatically, in case that water is drawn out from blow-offs or escapes from a rupture in the pipe. The investigations for determining the proper size of such a fixture at any particular summit are extremely interesting, but lack of space prevents their introduction here. It will therefore suffice to say that three different sizes, affording clear openings of 3, 4 and 6 inches in diameter, were used in the work. The devices consist respectively, of one, two and four similar bronze valves, suspended from springs and attached to a suitable cast-iron chamber, which is bolted to a horizontal stop-valve, and the latter to a flanged casting riveted upon the pipe. The stop-valve is left wide open, but if the air-valve gets out of order, the former may be closed and the repair made without shutting off the conduit. As it is necessary to keep these fixtures free from frost, earth and mischief, they are enclosed in an iron case deeply covered with earth, and from which a capacious stand-pipe projects about 3 feet above the surface of the ground. The top of this stand-pipe is covered with an iron hood, in which there is a small opening, also covered with a locked flap, to receive the key whereby one of the clusters of air-valves may be pressed down and opened. For the admission of air, the valves are all opened automatically by the pressure of the atmosphere as soon as the water-pressure is removed, since the tension of the springs is only sufficient to balance the weight of the metal.

Corresponding to the air-valves, a blow-off for emptying the pipe, in case of cleaning or repair, was provided in every depression. One of these was made 8 inches in diameter, and all the others were 6 inches. They consisted of two stop-valves bolted together, and to a flanged casting riveted on the lower quarter of the pipe, the valve nearest the latter being kept open and regarded

as a reserve in case of injury to the other one, which is ordinarily kept closed. An iron pipe leading to the natural watercourse or drainage ditch in the depression serves to carry the outflow, when the valve is opened, to some distance from the conduit. At each blow-off, both the main pipe and the pair of stop-valves are supported upon a bed of concrete, so as to reduce the danger of any breakage in the connection from unequal settlement.

Ten large and heavy 36-inch stop-valves are placed in the line of the conduit from its beginning to Rush reservoir, and six such valves are set between Rush and Mt. Hope reservoirs. Of the former, five are placed in such positions that if a parallel conduit about 2.56 miles in length is ever required through that portion of the valley where the new conduit crosses nine times under Honeoye Creek, three connections between the two can be made so as to divide this somewhat hazardous part of the route into two sections, either of which can be cut out by means of these valves without greatly impairing the efficiency of either of the two lines. Provision has also been made for connecting with the old conduit at two points, the first at Richmond Mills, where the old pipe may be made to partially supply the new line, and the second near North Bloomfield, where the relative elevations first become such as to enable the new line to feed the old one. There is, however, no immediate necessity for making any of these connections, and facilities therefore have been provided only because it is probable they will become desirable at some future time.

The old and new conduits are also connected indirectly in the new gate house at Rush reservoir, where a complexity of valves is found necessary for the purpose of avoiding grave annoyances in the future, when another conduit from Hemlock lake is built. The pipes and valves have here been arranged so as to allow any of the conduits coming to said reservoir to feed any of the pipes leaving the same for Mt. Hope reservoir. A similar provision has also been made at the point in Pinnacle Avenue, about 400 feet north of Elmwood Avenue, where the present new pipe deflects abruptly to Mt. Hope reservoir, the intention here being to treat the deflected line as a branch to said reservoir, while the conduit itself is continued to a new distributing basin, as previously mentioned.

Another large group of valves occur in the new gate house at Mt. Hope reservoir, where the new conduit is directly connected

with two new 36-inch distributing mains. These latter pipes are also designed to take water from the reservoir; but as it may become desirable at times to obtain a somewhat higher pressure in the city than is afforded from said reservoir, it has been planned to equip each of these pipes with a check-valve, which will close automatically when they are fed from Rush reservoir, and will reopen when the connecting valves are shut.

A few words with respect to the connections of the new conduit with the two reservoirs may also be of interest. For the present, only temporary connections have been made by means of a short line of 16-inch pipe laid over the bank at each locality; but as the available pressure is large enough to deliver from ten to twelve million gallons per day through both lines, they are amply sufficient until next summer, when the permanent connections will be made. In the performance of this work, it will be necessary to empty both reservoirs and keep the water out for some time, in order to cut through the banks, lay the various large inlet and outlet pipes, construct the masonry screening wells, and finally refill the excavations; and as it was expedient to have full assurance from long continued good service, that the new conduit would not require shutting off for repairs during this period, the work was accordingly postponed.

Much more might be added to the foregoing by describing the extensive preliminary grading work which was done in several portions of the route before the pipes could be delivered, as well as the difficulties attending the completion of the crossings under Honeoye creek and the several lines of railway; but as space for this is not now available, and nothing has yet been said of the coustruction of the masonry conduit and the intake pipe, these portions of the work will next be considered.

The reasons for adopting a diameter of 6 feet, and a grade of one in 4000 for the masonry conduit, from Hemlock Lake to a point about 12,000 feet northerly, have already been indicated, and we may, therefore, pass to the description of the work itself. From numerous test borings, it was found that the firmest subsoil at the contemplated depth below the existing ordinary low-water level, occurred over a comparatively small area at the northeastern corner of the lake. This place was accordingly selected for the site of the gate house, and the route of the conduit in earth excavation was governed by similar considerations. It was also

aimed to secure the utmost stability for the work by reaching tunnel work in rock as quickly as was consistent with the shortest expedient length of line, since there was little difference in the cost of the finished conduit, whether tunneling was done in earth or in rock. From the contract prices, it was found that when the depth of an open trench in earth reached a limit of 30 feet, the cost per lineal foot of the completed structure would be the same as if the work were done in tunnel, and hence this depth of 30 feet became the dividing line between the two classes of excavation.

An examination of the profile of the route shows that at the beginning of the conduit proper, which is about 100 feet from the shore, the ground is some four feet above the ordinary low-water level, and hence that the excavation would here be about 22 feet deep. From this point northerly the ground gradually rises, until at a distance of 395 feet, the depth of cutting becomes 30 feet. Continuing along the route, the surface rises rapidly to shaft No. 1, which is 68.3 feet deep, and it does not again reach to within 30 feet of the required bottom grade of the conduit for a distance of 7350 feet. In the remaining length of 4184 feet to the end of the work, the depths of excavations are all less than 30 feet, the average being 13.3 feet. The contractors were accordingly directed to tunnel the said distance of 7350 feet, and to make an open trench for the remainder of the way; but as they preferred to continue the tunneling for some distance beyond the limits at the same prices as for the work in open excavation, no objection was made.

To expedite the tunnel work, six shafts were sunk at nearly equidistant and favorably situated points along the route, thus affording, with the two end points, fourteen places at which excavation could be prosecuted simultaneously. The depths of these shafts ranged from 54.7 to 78.0 feet, the average being 67.2 feet, of which 9.7 feet was in earth and 57.5 feet in dense shale rock. The power for operating the rock drills was compressed air, which was transmitted through a long line of 4-inch wrought-iron pipe, from a centrally located station to each of the shafts, and afterwards also to the north portal. Work was first commenced on March 2, 1893, at shaft No. 3, and soon afterward at the other five. As this shaft was the shortest, its excavation was finished on April 14th, when tunneling was first begun in both directions.

On May 5th the last of the other shafts was finished, and tunneling could then proceed from twelve points of attack. As the material at one of the two portals was clay, while at the other soft and friable rock occurred, the excavation at these points was delayed by the contractors until the principal rock work was well under way.

The tunnel work was prosecuted continuously throughout the twenty-four hours of each day, except Sundays, at a maximum rate of 8.33 feet, and an average rate of 5.71 feet per day, at each of the twelve headings. On August 8th the headings met between shafts No. 2 and No. 3, and within a few weeks the other headings met, so that on September 1, 1893, a continuous passage was formed between shafts No. 1 and No. 6, a distance of 5875 feet. Work at the two ends or portals was begun on August 15th and 24th respectively, timbered shafts 30 feet deep to grade being sunk at these points. From the south portal the excavation was in clay southerly to the gate house, also northerly for 210 feet, after which it passed into and through soft shale rock for a length of 130 feet to hard and dense rock; from the north portal southerly a similar soft rock was encountered for 224 feet, also for 50 feet northerly, when the excavation passed wholly into clay. The work in this soft rock and clay was somewhat dangerous, and both the roof and sides of the tunnel here required heavy timbering and sheathing. In the firm rock, on the other hand, the roof needed no support, and but little trouble from the falling of material was experienced. Progress from the portals was therefore somewhat slower than from the shafts, the average rate being about 5.0 feet per day, yet on October 16, 1893, the excavation of the entire distance of 7350 feet between the portals was completed.

Meanwhile, work on that portion of the conduit which was to be built in open trench was also in full progress, it having been commenced on July 17, 1893, near the northern terminus of the route. The excavation was mostly through plastic clay, although two deep cuttings through rock were also necessary. In the former material considerable bracing and sheathing of the sides of the trench was required, so as to allow the construction of the conduit to proceed without danger. For this purpose the bottom of the trench was neatly shaped to the prescribed concave form and grade, and upon it was deposited a layer of concrete 6 inches

in thickness, with its upper surface carefully adjusted to the shape of the brick-work. After the concrete had hardened sufficiently, the invert or bottom of the conduit was formed by a single course of brick. The curved brick side walls, 8 inches thick, were next built true to line, from wooden forms, up to the level of the centre of the semi-circular arched roof; and while this work was going on, the intervening space of about 12 inches between the exterior of the brick walls and the sides of the excavation was compactly filled with concrete. Wooden centres were then put in place, over which the brick arch was turned in two courses, each of 4 inches thickness, and covered with a thick coating of mortar, after which the concrete backing was carried up for 17 inches and sloped off evenly towards the top of the arch.

All of the brick-work was laid in Portland cement mortar, whereas the concrete was formed with Natural cement. The roof was allowed to remain exposed until the concrete had become hard; whereupon the trench was refilled and the original surface of the ground restored, except in a few places where the excavation was very shallow, and an embankment was necessary to protect the masonry from frost. In such cases the embankment was carried to a height of 3.5 feet above the top of the arch, and the filling was also extended back to the hillside in order to avoid the formation of pools. Some delays occurred in the supply of materials for the conduit during the fall, and as it was desirable that the open work should be completed before severe cold weather set in, the contractors devoted most of their energy to the accomplishment of this end. The work was therefore pushed with the utmost diligence, and was finally completed, along with the overflow chamber at the northern terminus, early in January, 1894.

Up to this time little progress had been made in constructing the brick lining of the tunnel, except where the excavation was through soft ground and the timbering had commenced to settle; but after the aforesaid operations outside were finished, work in the tunnel was actively resumed. The masonry was begun midway between each of the shafts, and was thence carried along in both directions to the latter. Where the rock was hard and sound, the side walls and arch were made of two rings of brick, or 8 inches in thickness; and, as in the case of the conduit in open excavation, the entire space between the exterior of the brick-work and the rock sides was filled with concrete to near the top of

the arch, above which the space was filled with fragments of stone from the excavation, all tightly packed or rammed into place. It should also be stated that on removing the *débris* and exposing the sound rock on the bottom of the tunnel, its surface was found to be very irregular, owing to the action of the explosives; and it was therefore determined to make this bottom smooth and uniform in grade throughout by filling up all depressions with concrete, the lower portions of this filling, up to 4 inches below grade, being made with Natural cement mortar, while the top layer was made with Portland cement mortar. The bottom of the tunnel is accordingly as smooth and true to grade as a good cement sidewalk, and some advantage will result therefrom in the future by enabling the tunnel to be easily cleaned by a suitable sweeping-machine.

In soft rock excavation, the bottom of the tunnel was lined with one course, four inches thick, of brick; but in earth excavation two courses, in addition to the concrete, were used to form the floor. In other respects the construction was similar to that already described, except in places where the rock roof was very thin and loose. At these localities the side-walls and arch were formed of three courses of brick; and at the shafts, where great strength was required, the brick-lining masonry was made four courses, or 16 inches thick. The aggregate length of the 12-inch brick lining is 434 feet, and that of the 16-inch lining, 132 feet. In each shaft a brick manhole was built after the tunnel masonry had been finished, which was provided with a vertical iron ladder, resting-platforms about 25 feet apart, and a strong iron coping at the surface of the ground. The resting-platforms were designed to be capable of being folded back against the brick work so as to afford an unobstructed passage for large buckets from top to bottom in case of future repairs or cleaning operations in the tunnel; and the top casting was furnished with a tight-fitting, locked cover, and a 6-inch ventilating-pipe terminating in a suitable hood.

It may also be remarked that a 6-inch ventilating-hole was drilled at some convenient point between each pair of shafts, as it was anticipated, from the preliminary borings, that some natural gas might be encountered. Most of these holes have been retained for use hereafter, and the tops of the iron casing-pipes are now provided with hoods, as at the shafts. Two relatively short manholes were furthermore built over the conduit in open excavation,

so that in addition to the ends, access to the work can be gained at eight different points along the route.

The tunnel masonry was completed on July 6, 1894, but before it could be used for conveying water to the pipe conduit, the interior of the whole work had to be scraped, washed and thoroughly cleaned, as considerable quantities of waste mortar, sand, mud and soot had gradually accumulated therein. After having been carefully cleansed, the surface of the brick-work was given a thick coating of neat Portland cement, which was applied as a wash with large brushes, and rendered the whole conduit as clean as the most fastidious could wish.

Some reference to the work of constructing the large gate-house on the shore of the lake at the south end of the conduit should also be made. Excavation was begun on August 23, 1893, and a timber foundation on a bed of clay was obtained on October 26th. From the insufficiency of the bracing, however, the sides slipped in and caused a serious disturbance of the material on the bottom. After clearing the site several times, about one hundred piles were driven in December at relatively close intervals over the whole surface into a hard stratum below, and a secure foundation was thus obtained. The piles were capped with heavy timbers, over which another course of similar timbers was laid transversely, and concrete was then rammed into the rectangular spaces of the grillage up to the top of the upper course of timber. Another layer of fine concrete was then deposited over this surface, both as a precaution against leakage and to form the footing course of the walls. As no suitable stone could be found anywhere in the locality, the thick walls were built entirely of brick-work, laid in Portland cement mortar. This remark is also applicable to the case of the overflow chamber at the north end of the conduit. The masonry of the gate-house was begun on January 11, 1894, and was completed up to the level of the contemplated flooring on April 24, 1894, the work also including the laying in concrete of the first length of 38.6 feet of the 5-foot steel intake pipe. During the winter the excavation was covered with a temporary wooden roof, and the enclosure was kept warm enough to prevent the masonry from becoming injured by frost.

The gate house is arranged with two sets of passages to the conduit, both to secure ample area of screen surface, and to allow one set of sluice valves to be repaired without interrupting the

water supply to the conduit. For the latter purpose, the openings through the partition walls are provided with strong iron guides for stop planks or shutters, so that any compartment may be isolated. A subterranean chamber was also formed at the mouth of the conduit, in which a weir can be placed for accurately measuring the supply taken to the city; and by removing this weir, room is afforded for launching a boat, either for making an examination of the tunnel at any time or for attaching a sweeper. It may be mentioned, in this connection, that while the conduit is 6 feet high and wide inside, the maximum depth of water therein will not exceed 4 feet, unless it be desired to waste it at the overflow chamber.

From the character of the work connected with the laying of the large intake pipe, little could be done in this direction until the gate house was finished. An agreement for its performance was made on April 14, 1894, with Chambers & Casey, of Rochester; but active operations were not commenced until May 16th, as the intervening time was needed to obtain materials for building scows for the dredge, the pile-driver, and the pipe; also for constructing the various temporary supports, and procuring the necessary machinery and appliances. The 5-foot steel pipes, with their ball and socket joints, had been delivered and riveted together in lengths of about 100 feet during the preceding fall and winter, and arranged in proper order upon a platform in a convenient field. Their weight ranged from 14 to 18 tons, according to the thickness of the plates, and the number of stiffening rings. To transport these heavy tubes safely, a narrow gauge railway track was laid between the two rows of pipes and down the gently sloping bank to and over a pile pier, at the end of which a powerful hoisting machine was placed on a framework overhead. A pipe was then rolled upon two small trucks and conveyed to the end of the pier, where one-half its weight was transferred from the foremost truck to a pontoon or scow, which was then pushed out a certain distance and held in place; the pipe was then lifted from the rear truck and lowered upon a second scow, which had been slipped underneath, so that it now rested on two floating supports; whereupon it was easily towed to its required position between two well-braced clusters of piles, which had meanwhile been driven in the line of the work, and which were provided with hoisting machines on their tops. The pipe was then lifted from the two scows and held in place by strong chains at each end.

This method of transportation was adopted for all the pipe, except the first long one, which was moved to the gate house by rolling on timber ways carefully bedded in the surface of the ground. Other work, however, was necessary before any pipes were moved. A steam dredge had to cut a channel, giving about 20 feet depth of water, and sufficient width on bottom to allow it to operate advantageously, from a point in the lake about 800 feet from the shore, towards the latter to meet the open excavation for the first pipe, which was done mainly under the protection of a low dam built in the shallow water near the shore. This plan was pursued both to expedite the work, and to avoid the necessity for a diver in coupling together the ball and socket joint at the junction of the first long pipe, and the short one which had previously been laid along with the foundation of the gate house. Borings had shown that, to this extent at least, an open excavation, with side slopes of one and one-half to one, could readily be made in the plastic clay; and this was proved by the subsequent easy performance of the work. After this earth was removed, the first long pipe was rolled down the side slope of the pit by means of check ropes, and placed approximately in line on the bottom.

Several thick piles 65 feet in length, which was sufficient to span the top of the excavation, were then rolled along from the south bank, so as to form a bridge or platform over the end of the pipe. A few supports from below enabled this platform to carry a light pile driver, the engine of which was left on the bank, whereupon a cluster of six piles was driven on each side of the pipe, and thoroughly braced. The tops of these piles projected 10.5 feet above the water surface of the lake, and were capped transversely with heavy timbers, the caps being in turn tied together by similar longitudinal timbers. The space of about 14 feet between the two groups of piles was then bridged over with other timbers, upon which a hoisting machine was placed, whereby the south end of the pipe could subsequently be lifted above water surface. At its north end, the pipe was raised to the slight required height with jack-screws, and then slid along until the ball of the joint was properly fitted into the socket of the pipe projecting southerly from the gate house, whereupon the coupling collar of the ball was securely bolted to said socket, thus completing the first joint or flexible union of the two pipes.

As the above-mentioned short pipe was firmly held in place

both by the thick wall of the gate-house and the large mass of concrete in which it was enclosed, also by the clay backfilling over the latter, the south end of the first long pipe could now be moved about freely, and it was therefore raised up and held in place with a chain sling until the dredge had completed the aforesaid channel, and formed a communication with the open pit. A second cluster of piles, like the first, was then driven in the channel at the proper distance from the second ball joint, and provided with a hoisting machine, whereupon the second long pipe was brought into position, raised from the scows and coupled to the first one above the water surface. It will be noticed that only one hoisting machine was placed on each of the clusters of piles, the one at the open or south end of the second pipe being soon relieved from duty by a chain sling, whereby it became available, with a little shifting, to lift the north end of the third pipe. The sling at the south end of the first pipe could now be released by throwing the entire weight at the second ball joint upon the first hoisting machine, whereupon the joint could be lowered down to place on the bottom of the channel; but before doing this a strong timber and plank platform was attached to the joint in order to prevent undue sinking into the soft clay bottom. As soon as the platform and joint rested on the bottom, the hoisting machine was free to be moved to the third cluster of piles. By repeating these operations, all of the fifteen pipes were finally sunk in place.

The end of the last pipe was provided with a wide, flaring mouth-piece, which was enclosed in a strong, timber crib, 16 feet square and 10 feet high. Two sides of this structure were divided into compartments; and when it was ready for sinking, these were loaded with stone distributed in such manner as to produce a nearly uniform pressure upon the lake bottom. As the connection of the crib and mouth-piece did not admit of much motion, it was necessary to lower the last pipe and the crib simultaneously, and in a horizontal position, which was easily done with the hoisting machines and guide ropes. It should also be stated that after the pipes had been laid in the aforesaid deep channel, the latter was partially refilled by the dredge with material taken from the adjacent sides, in order that no subsequent sloughing or caving might cause a displacement of the pipe; the large excavation at the shore was likewise refilled. All piles were pulled out as soon as they had served their purpose in any locality, and, if practica-

ble, were again used elsewhere in the work. The same course was also pursued with the other materials.

The crib, which completed the new intake work at the lake, was sunk on October 6, 1894, the first long pipe having been put in place on August 14th. Dredging was begun on June 25th, and on August 21st, connection was made with the open excavation at the shore, although only a portion of the channel was at that time finished. As the clusters of piles at the pipe joints could not be driven until the dredge had cut the required channel, progress with the pipe laying was somewhat slow; but after leaving this channel, the floating pile driver was kept at work constantly, and the pipes were laid as fast as the pile clusters could be completed. The work of launching, transporting, connecting and laying each pipe occupied only a few hours, and had the dredging and pile work all been done in advance, the pipe work alone could have been completed in ten days.

Early in the season it was realized that the above-described permanent intake work could not be finished before an ample supply of clean water from the lake would be needed for washing out both the tunnel and conduit masonry and the steel pipe conduit, which latter was expected to reach Rush reservoir in June. To avoid delays anywhere in the work between the lake and said reservoir, and in order that the earliest advantage could be taken of the considerably greater discharging capacity of the portion of the old conduit between Mt. Hope and Rush reservoirs, over that of the portion between Rush and the lake, a temporary intake was formed early in July, 1894, with a line of 16-inch pipe, about 720 feet long, which was laid as a siphon from a small plank basin on the shore of the lake, and directly communicating therewith, to the bottom of the gate house. This line of pipe was provided with a stop-valve at each end, and by closing the same, the siphon could readily be charged in a short time by filling it with water from a small steam pump. By closing the orifice for filling on top, and then opening the two stop-valves mentioned, the siphon was at once set in operation, and was able to deliver clean water from the lake at the rate of about 8,000,000 gallons per day.

This rate was amply sufficient for every purpose, and the pipe remained in service until the permanent works were completed, on October 6, 1894. It was taken up soon afterward and returned to the city for future use in the distributing system, while

the plank and boards of the suction basin now form part of the temporary roof over the gate house. It may also be mentioned that water from the siphon was first admitted into the tunnel for cleaning purposes on July 16, 1894, and that this operation occupied a full month, during which time the masonry was subjected to repeated scrubbings and flushings. On August 17th the water was first admitted into the steel pipe, which was also flushed thoroughly a number of times before the temporary inlet pipe to Rush reservoir was opened. The pipe from Rush to Mt. Hope reservoir was treated in a similar manner, and it is fair to state that when the inlet valves at the two reservoirs were first opened, the water issued as clear and clean, so far as the senses could detect, as when it left Hemlock Lake, 26 feet below its surface.

Some further statistics relating to the work will doubtless be of interest.

The material actually excavated in the performance of Contract No. 1 was about 46,600 cubic yards, of which 24,700 were in open trenches, and 21,900 in the shafts and tunnel. The volume of masonry built was 13,289 cubic yards, of which 278 was stone work of various classes, 6155 concrete, 1085 brick work in the gate house and overflow chamber, and 5771 in the conduit, tunnel, and shafts. The brick work represents about 3,700,000 bricks. Over 55 tons of iron work were put in place, and the number of men employed daily ranged from 100 to 400 during a period of sixteen months.

The work performed under Contract No. 2 embraced approximately 57,200 cubic yards of preliminary grading for roadways and reducing depth of backfilling, of which 2200 were in rock; 202,000 cubic yards of excavation in trenches for the pipe, of which 1300 were in rock; 4270 cubic yards masonry of various classes; 210,000 feet, board measure, timber and plank in foundations and bridges; 6500 linear feet of piles driven for bridges and pipe foundations; 53,367 linear feet ¼-inch plate pipe, single riveted; 24,729 linear feet ¼-inch plate pipe, double riveted; 34,815 linear feet $\frac{5}{16}$-inch plate pipe, and 24,043 linear feet ⅜-inch plate pipe, both double riveted; 1321 linear feet 36-inch cast-iron pipe, special castings and stop-valves; the total length of pipe conduit thus being 138,275 linear feet, or 26.19 miles. The first shipment of steel pipe from the East Jersey Pipe Works arrived on April 26, 1893, but laying was deferred until June 8th, as a large

amount of heavy grading along the first two miles of the route had to be finished before any pipe could be delivered or the trench opened.

On December 21, 1893, the pipe conduit was completed to Rochester Junction, on the Lehigh Valley railroad, a distance of about 13.6 miles from its beginning, near Hemlock Lake, and further operations were suspended for the winter. During the preceding period the average rate of progress in pipe laying was 500 feet per day. Work was resumed on April 6, 1894, and as the weather continued favorable, very rapid progress was made, Rush reservoir being reached on May 14th and Mt. Hope reservoir on July 26th. The maximum rate of progress in pipe laying was 1860 feet in one day, and the average for the entire work was 598 feet per day. Much work, however, remained to be done in testing, recalking, attaching air-valves and blow-offs, setting main stop-valves, painting and cleaning the pipe, and making temporary inlets at the two reservoirs; and it was not until August 24th that the water was first let into Rush reservoir, and October 9, 1894, into Mt. Hope reservoir. The number of men employed daily along the line of work ranged from 300 to 600.

An important element in the problem was the acquisition of the necessary rights of way for performing the work over a route 27.8 miles in length, where the ground was not already owned by the city. Of this distance, 20.6 miles was through private lands, and 7.2 miles in highways. The title to the area occupied by these roads was, however, vested in the adjoining landowners, and hence it became necessary to negotiate with the latter for the right to lay the pipe, precisely as if the line were located in private grounds. Much diplomacy was needed to obtain these rights without causing delay to the contractors, especially as no limit was placed on the number of conduits which the city might lay in the territory sought, also because it was stipulated that no damages to crops grown thereon in the future should ever be paid. Out of a total of 140 landowners along the route, it was found necessary to apply for legal condemnation proceedings and arbitrations in only 13 cases. The total costs of these rights of way, including all legal expenses involved thereby, was about $57,900, or about $2084 per mile on the average.

It would also be interesting to give a statement of the entire cost of the work up to the present time, but as it embraces a large

number of items which could not be properly collated in season for this paper, only the principal expenditures can now be presented approximately. For the intake work, gate house, and masonry conduit, the cost has been about $318,000; for the steel pipe conduit with the appurtenances named in the contract, $1,200,000; for valves and structures which were to be provided by the city aside from the general contracts, $29,000; for rights of way, $57,900; and for engineering and inspection, $80,000; total, $1,684,900. This amount does not include payments made for prospective damage to mill privileges, or a great variety of incidental expenses; and there should, furthermore, be added the costs of completing the permanent connections at the two reservoirs, as well as those for the erection of suitable buildings over the several gate chambers at Hemlock Lake and Mt. Hope reservoir. No contracts for these latter items have yet been made; and as the work involved will necessarily be expensive, it is fair to presume that the original appropriation of $1,750,000 will be fully exhausted.

Before concluding this paper, the writer desires to acknowledge the generous support and substantial co-operation of the Executive Board in all the work outlined above, as well as their large participation in the many anxieties and worries which always accompany the design and execution of such an important and costly undertaking. He also takes pleasure in acknowledging that in the successful performance of the work, great credit is due to the several contractors, and furthermore, to the activity of the City Attorney and Mr. Jerome Keyes in obtaining the necessary rights of way.

ABSTRACTS.

ANALYTICAL CHEMISTRY, BY E. WALLER, PH.D.

Ammonium Thioacetate as a Reagent. Schiff and Tarugi (*Ber.*, xxvii., 3437). The inconveniences of H_2S are well known, and therefore a substitute is sought in the use of an acidified solution of ammonium thiosulphate ($NH_4C_2H_3OS$), which, by heating, affords H_2S and acetic acid, the ammonia uniting with the acid used in acidifying. It is recommended to make the acid by the action of P_2S_5 on glacial acetic acid, to dissolve it in a slight excess of ammonia, and then to dilute so that 30 c.c. of the solution represents 10 c.c. of the acid. It should be kept in small bottles having corks carrying pipette tubes graduated to deliver 2 c.c. at a time, which suffices for 0.5 to 1 gramme of material taken for analysis. After adding the reagent to the acidified solution, warm the mixture to just short of boiling, allow to cool, and then filter, testing the filtrate in the same manner. Treated in this way, arsenic acid solutions precipitate readily; also all other members of the H_2S groups. The reagent can be used in ammoniacal solution for the $(NH_4)_2S$ group, but its use does not afford so much advantage as is the case with the H_2S groups.

Barium Thiosulphate for Standardizing Iodine Solutions. Plimpton and Chorley (*Proc. Lond. Chem. Soc.*, No. 149, p. 38). 50 grammes $Na_2S_2O_3$ crystals and 40 grammes $BaCl_2$ are dissolved each in 300 c.c. of water, the warm solutions mixed, and the crystalline precipitate which soon separates is collected, washed, and dried at 30° C. Its composition is BaS_2O_3, H_2O. It keeps well, and when suspended in a solution reacts promptly with I. In using it for standardizing, the flask should be frequently shaken. The product of the reaction, BaS_4O_6, is soluble in water.

Sodium Cobalt Nitrite as a Reagent for Potassium. Van Eyk (*Chem. Centr.*, 1894, i., 1162). Prepared by adding 100 c.c. of a 60 per cent. solution of $NaNO_2$ to 30 grammes $Co(NO_3)_2$ in 60 c.c. of water. Filter, and precipitate with alcohol. Will detect 1 in 10,000. Will also detect ammonium 1 in 2000.

Alkalimetric Titration of Hydrates and Carbonates. Kippenberger (*Zts. f. Angew. Chem.*, 1894, 495). In solutions of the alkalies, phenolphthalein, blue de Lyon, and alkannine give decided change of color when standard acid has been added until bicarbonates only are present. In titrating $MgCO_3$ in the same way, only phenolphthalein gives sharp results. Other indicators were tested: hæmatoxylin, gallein, gentian blue, Poirrier blue, sulphindigotic acid, and flavescin. These are not so generally satisfactory. Hæmatoxylin is serviceable for titrating $MgCO_3$

in presence of not too large amounts of alkaline carbonate. $MgCO_3$ gives blue, whereas alkaline carbonate and $MgH_2(CO_3)_2$ gives a red violet (purpurviolett).

Alkaline Hydrate and Carbonate in Presence of Alkaline Cyanides. Clennell (*Chem. News*, lxxxi., 93). The method prescribed is:

1. Estimate cyanide by direct titration with $AgNO_3$.
2. Estimate alkali hydrate + half the carbonate by adding phenolphthalein to the same solution, and continuing the titration with HCl.
3. Estimate total alkali by direct titration (with HCl), using methyl orange as indicator.

Acidimetry of Hydrofluoric Acid. Haga and Osaka (*J. Lond. Chem. Soc.*, lxvii., 251). Phenolphthalein is the best indicator when KOH or NaOH is used. Rosolic acid is nearly as good, and may be used with ammonia. Cochineal and Brazilwood give satisfactory results. Brazilwood paper gives unsatisfactory indications. Turmeric paper is fairly good. Methyl orange is useless.

Litmus, lakmoid, and phenacetolin can be used, but require experience. Some phenomena with litmus tend to suggest that the acid may be H_3F_3 or H_4F_4.

Iron and Alumina in Phosphates. McElroy (*J. Am. Chem. Soc.*, xvii., 260). More extended experiments have convinced the author that the method which he described as satisfactory for his purposes at the time (*vid.* QUARTERLY, xiii., 177), proves in some cases entirely untrustworthy. —Precipitating by ammonia after separation of P_2O_5 by molybdate.

Separation of Iron, Alumina and Chromium. R. B. Riggs (*Am. J. Sci.*, xlviii., Nov.) Having a precipitate containing these metals as hydroxides, about 0.1 gramme of each, suspend in 100 c.c. of water, and add 10 c.c. of H_2O_2 solution and 1 gramme Na_2O_2. Digest until effervescence of O ceases. $Fe_2(OH)_6$ only remains undissolved, Al and Cr going into solution, the latter as Na_2CrO_4. In the filtrate from the iron the Al may be separated by ammonia, leaving Cr to be managed by any convenient means.

Zinc Determination. Shimer (*J. Am. Chem. Soc.*, xvii., 310). A plan recalling some points in that of Low (*vid.* QUARTERLY, xiv., 40). Dissolve 0.8 gramme of the ore in HCl. Evaporate to dryness. Unless SiO_2 is to be determined, it will be unnecessary to filter at this point. Dissolve in HNO_3 and precipitate Mn by $KClO_3$. Determine by Williams' method. Evaporate the filtrate from MnO_2 to dryness, add a little HCl and evaporate to "moist dryness." Make double basic acetate precipitation, precipitate Zn in acetic solution by H_2S. Dissolve and determine as pyrophosphate.

Analysis of Zinc and Copper Alloys. Warner (*Chem. News*, lxxxi., 92). Dissolve with strong H_2SO_4 in a flask, dilute, add Mg ribbon, heat to 100° F., and allow the action to go on until the solution gives no reaction for Cu by KCyS. Separate the metallic Cu, which, if the alloy contains Sn, etc , must be further examined, and to the clear solu-

tion add strong $NaC_2H_3O_2$ solution and boil. Add Mg (preferably in the form of thick sheet or rod) which will then precipitate the Zn.

Qualitative Separation of Nickel and Cobalt. Villiers (*Bull. Soc. Chim.*, xiii., 170). NiS is more readily soluble than CoS, or prevented from forming as an insoluble compound by several alkaline salts. If to a mixture of Ni and Co salts one adds tartaric acid and then a considerable excess of NaOH (not KOH), on saturating with H_2S, CoS separates, and Ni remains in solution, imparting a brown color to the liquid, the intensity of which is proportional to the amount of Ni present. An NiS compound, soluble under the conditions produced, is formed.

Heat should not be applied, and ammonium salts should be absent.

Nickel in Nickel Steel. Campbell and Andrews (*J. Am. Chem. Soc.*, xvii., 125). In an Erlenmeyer flask, dissolve 1 gramme in 25 c.c. HNO_3 (Gr. 1.2) and boil out the nitrous fumes. Add freshly dissolved $Na_4P_2O_7$ (13 grammes in 75 c.c. *cold* water). Then add a 20 per cent. solution of Na_2CO_3, with stirring, until the ferric pyrophosphate precipitate just redissolves. Avoid excess of Na_2CO_3, which would give a red solution. Filter through asbestos into a half litre Erlenmeyer flask, and wash with a little water. Then add to the solution 2 grammes potassium xanthate freshly dissolved in 20 to 25 c.c. water. (The reagent does not keep when in solution). Stopper the flask and shake at intervals for ten minutes. Ni precipitates as xanthate (brick-red) free from Mn and Fe, but containing Cu if that is present. Filter rapidly through asbestos, and wash four or five times with 1 per cent. solution of xanthate. The xanthate solutions should not stand over fifteen to twenty minutes before being used. Dissolve the precipitate $Ni_2(C_3H_5S_2)O_2$ in 10 c.c. fuming HNO_3, diluted with 10 c.c. of water, into a small flask; wash with hot water, then pass through the filter 5 c.c. H_2SO_4 (dilution 2 : 3) and wash again with hot water. Boil down to sulphuric fumes, cool, add 20 to 25 c.c. water, heat to boiling, and pass H_2S to separate Cu. Filter, washing with dilute H_2S water. Boil out H_2S, oxidize the small amount of Fe remaining by adding H_2O_2 or Na_2O_2, and precipitate it out with ammonia. Redissolve in dilute H_2SO_4 and reprecipitate. Boil and filter. In the solution, determine Ni, either:

1. *Electrolytically* by adding 30 c.c. of 10 per cent. Na_2HPO_4 solution and 25 c.c. of strong ammonia. Make up to about 175 c.c. and electrolize for twelve hours with a current of 0.14 ampere per 100 $cm.^2$ area of the dish. Or,

2. *Volumetrically.* Cool completely. If necessary, add enough ammonia to give a distinct odor of NH_3. Add 5 c.c. $AgNO_3$ indicator (0.5 gramme $AgNO_3$ per litre) and 5 c.c. of .2 per cent. KI. Titrate with standard KCy (1 c.c. = 0.001 gramme Ni). So long as there is any Ni uncombined as K_2NiCy_4, the AgI cloud remains undissolved, the end reaction being when the solution clears by solution of the AgI in excess of KCy. The standard KCy solution is made by dissolving 4.5 grammes in water and making up to one litre. Standardize with pure Ni. Commercially pure Ni wire contains 99.5 to 99.5 per cent. Dissolve about 1 gramme in HNO_3; evaporate; precipitate Fe as basic acetate; add a little H_2SO_4 and dilute to get the proportion of 1 gramme Ni in the litre. Use 25 to 30 c.c. of this solution for each standardization.

Electrolytic Separations of Iron, Cobalt and Zinc. Vortmann (*Chem. Centr.*, 1894, I., 877). In an alkaline tartrate solution with a current of 0.07 to 0.1 ampere, Fe is deposited free from Zn. The electrolysis should begin in the cold, the temperature being raised to 50 or 60° C. at the finish. The cathode may be frequently changed with advantage. After removing the Fe the Zn may be separated by using a current of 4 volts. Co is better separated from Zn in an alkaline tartrate solution by using 2 volts rather than 4. KI in the solution diminishes, but does not entirely prevent the separation of Co_2O_3 on the anode.

Tellurium in Copper Bullion. Whitehead (*J. Am. Chem. Soc.*, xvii., 280). Dissolve 25 to 50 grammes in HNO_3. Boil off excess of acid. Add solution of $Fe_2(NO_3)_6$ (0.250 gramme Fe). Precipitate with excess of ammonia and wash with dilute ammonia. The precipitate contains Se and Te. Dissolve in HCl, add tartaric, render alkaline with KOH and pass H_2S. Se and Te dissolve. Decompose the sulphides, etc., in the filtrate by HCl. Keep warm until H_2S has gone, filter off Se and Te sulphides. Dissolve these in aqua regia, evaporate to dryness, take up with HCl and precipitate by SO_2. Weigh Se and Te on a weighed filter after standing twelve hours. Boil in strong KCy solution, add HCl, which precipitates only Se, filter, etc., dry at 100° C., weigh and deduct.

Arsenic in Concentrated Sulphuric Acid. Stepanow and Miklaschewski (*Russian Techn. Journal* per *J. S., C. I.*, xiv., 188). Add 50 c.c. of the acid slowly to 30 grammes NaCl in 250 c.c. of water, then add a little $NaHSO_3$ and pass H_2S.

Halogens in Organic Compounds. Walker and Henderson (*Chem. News*, lxxi., 103). Modifications of the methods of Carius (heating in sealed tubes with excess of $AgNO_3$). The method consists in using a known amount of $AgNO_3$ and after the decomposition titrating the excess of Ag in the clear aqueous solution.

Carbon in Irons. Schneider (*Stahl u. Eisen.*, 1894, 1029). Three grammes of finely divided steel are mixed with 10 grammes of a mixture of 3 parts of Pb powder and 1 part Cu powder in a porcelain boat which is rested on asbestos in the combustion tube. In front of the boat is placed 10 to 20 cm. of CuO. When the boat has been brought to redness the current of O is admitted, when the metallic mixture takes fire. The gases produced are dried by H_2SO_4 and then absorbed by NaOH. After the combustion the current of O is maintained for ten minutes. The whole operation may be finished in forty-five minutes.

Carbon Determinations. Handy (*J. Am. Chem. Soc.*, xvii., 247). $Ba(OH)_2$ solution is recommended as an absorbent for the CO_2. The form of tube to contain the solution had best be an inclined tube with bulbs at either end, the axles of which are vertical. About 50 c.c. of the $Ba(OH)_2$ solution should be used. The determination may be made by filtering and weighing the $BaCO_3$, or by titrating the solution alkalimetrically, *a* by standard $H_2C_2O_4$ without filtering, or *b* by standard H_2SO_4 after filtering.

Quantitative for Nitrous Oxide. Kemp (*Johns Hopkins Univ. Circular*, xiv., No. 116). The method found to give the most satisfactory results was burning CO to CO_2 by means of the N_2O in a "grisoumeter" (enclosed incandescent Pt spiral) over Hg. The reaction was most satisfactory when the proportion of CO to N_2O was approximately 7 : 1. The presence of water was found to be incompatible with correct results, H being set free.

Valuation of Cement Rocks for Hydraulic Purposes. Lunge and Tocherny (*Zts. f. Angew. Chem.*, 1894, 481). Inasmuch as the burning for hydraulic mortars appears to result from the decomposing action exerted on the aluminous silicates by the CaO from the calcium carbonate in the rock, it is proposed to test by heating strongly a fragment of the rock, then pulverizing; treating with HCl (1 : 3) and filtering, then boiling up with 5 per cent. NaOH solution, filtering and washing well. The residue gives the proportion of undecomposed silicate. The method seems to give a good index of the value of the material, but further investigation is necessary to prove its general applicability.

New Element. Bayer (*Bull. Soc. Chim.* [3], xi., 1155). The element has been found in small quantity in red French Bauxite, with vanadium and molybdenum. No name has yet been given to it, nor has the atomic mass been determined.

BOOK REVIEWS.

MACHINERY FOR METALLIFEROUS MINES. By E. Henry Davies, F.G.S. 8vo. 564 pp. London: Crosby, Lockwood & Son. New York: D. Van Nostrand Company. 1894.

This book seems to be made up in large part of extracts from the catalogues of makers of mining machinery. We have identified no less than sixty pages of letter press, not including illustrations, taken verbatim from the catalogues of a prominent firm in Chicago, and it is presumable that further examination would reveal a similar source for many other pages of the book. The very general acknowledgement in the preface of indebtedness to "Messrs. Fraser & Chalmers and other makers of machinery for their assistance" does not prepare us for such wholesale reprinting of their trade catalogues. In most cases there is nothing in the book to indicate where the author's statements end and the borrowed material begins.

It is but fair to state that the material used has been selected with judgment, and the compilation is well put together. Even for those having access to this trade literature this book will be found to have a certain value as a convenient compendium. Nearly half the book is devoted to ore-crushing, concentrating and milling machinery.

H. S. M.

THE VENTILATION OF MINES. Designed for Use in Schools and Colleges and for Practical Mining Men in Their Study of the Subject. By J. T. Beard, C.E., E.M., S. of M. '77, Secretary of the State Board of Examiners for Mine Inspectors, Iowa. 8vo. 170 pp. New York: John Wiley & Sons. 1894.

In many respects this is an admirable book. The author is qualified by education and experience to speak with authority. In common with most writers on ventilation the author has devoted an undue amount of space to the mathematics of the subject, fully half of the book being devoted to the discussion of fundamental formulæ. In this mathematical part of the book the author arrives in some cases at conclusions at variance with those commonly accepted. In some instances he is right; but in others his results are questionable, if not erroneous. The book would be much improved by condensing these mathematical discussions and putting the greater part of this work in an appendix. Of the sixty-eight formulæ, so carefully deduced by the author, a large proportion have but little practical value. Our knowledge of the movement of air in ventilating apparatus and in mine passages is not yet sufficiently exact to permit the laws to be expressed mathematically in anything more than a general way, and a series of formulæ based upon this incomplete knowledge can only give approximate and often misleading results when used quantitatively. Mathematical formulæ are chiefly useful as illustrating the principles that should guide us in venti-

lating a mine, what to do and what to avoid doing. For this purpose a few simple formulæ are all that are necessary.

The non-mathematical part of the book contains many useful hints and suggestions, but has been written for the "practical mining man" rather than for the student; the author assuming on the part of the reader an intimate acquaintance with the ordinary details of mine ventilation. For example: Chapter XII., on the care of the mine as assisting ventilation, should be entirely rewritten to adapt it to the comprehension of students. A chapter on the distribution of air in mines should be added, with numerous maps and diagrams, similar to the one on page 105, to illustrate the disposition and use of airways, stopings, doors, regulators, crossings, brattices and the method of ventilating workings of different kinds.

It is, perhaps, captious and ungrateful to point out the shortcomings in a book which is in many respects one of the best that has yet appeared. The evident fitness of the author to deal with the subject in a more satisfactory manner, however, leads us to hope that he may in a future edition supply us with an adequate treatise adapted to the wants of students of mining as well as to the needs of the "practical mining man." H. S. M. and R. P., Jr.

MANUAL OF GEOLOGY. By James D. Dana. Fourth edition, pp. 1087, figs. 1575 and two maps. New York. 1895. American Book Company. $5.00.

The first edition of Dana's Manual of Geology appeared in 1863, the second in 1874, the third in 1880, and now the fourth, entirely rewritten, largely rearranged and vastly amplified and improved, has just been issued. The venerable author has had the unique experience of seeing his original *Treatise on Mineralogy*, rewritten by his son and made the standard work on the subject in English, and of issuing with his own hand his *Manual of Geology* in such form that it will not soon be displaced as the standard American text-book. It has proved the swan's song of its author, for almost at the very moment in which these words were written, the news came that he, who combined in a rare degree the close observer, the ripe and well-read scholar, the teacher and the just and courteous editor, has peacefully passed away in his eighty-third year.

Since its first appearance Dana's Manual has been an epitome of American geology, and the several editions give a very excellent survey of the history of its development in the last thirty years.

The first edition appeared when the early State surveys from 1830–1860 had completed their maiden reports. The broad facts of the geology and structure of the country east of the Mississippi river and bordering on it, were generally known, and what may be considered the first epoch of the development of geological science in the United States was closed by the breaking out of the war. Of the great West there were only scanty descriptions from a few exploring parties with whom a naturalist went, usually as the physician of the expedition. The itineraries were scattered and meagre, and served rather to sharpen interest than to satisfy it. Soon after peace was established the four national surveys were begun, respectively, under Hayden, King, Wheeler and Powell, and the more systematic results of these observa-

tions became available. Renewed interest was also felt in the older States and many volumes from new surveys amplified early reports. The treasures of extinct vertebrate life in the West were also opened by Leidy, Cope and Marsh, and extensive mining developments east and west enlarged our knowledge of mineral resources. The second edition had thus much to draw upon that was new. The final reports of the four western surveys were mostly complete and they had all been consolidated into the present United States Geological Survey, when the third edition drew upon their stores, and upon the vast increments in palæontology and all branches of geological science that were made from 1872–1880.

In the last fifteen years the activity of the national survey, in mining regions and general areal work has been marked. The State surveys in Arkansas, Texas, Missouri, Iowa, Ohio, and several others, have added their quota. But most important of all for a text-book, the correlation bulletins of the United States Geological Survey have appeared and have placed at general command the ripest results of our best workers. The fourth and last edition has therefore been issued at a no less opportune time than were the others.

In the new work one quickly notices changes in arrangement that have no doubt impressed many readers of the earlier editions, as needed improvements. Dynamical geology precedes historical as it naturally should. The chapter on Cosmogony that concluded the earlier issues has been practically omitted and its absence does not lessen the value of the treatise as a scientific text-book.

The pages devoted to physiographic, structural and dynamical geology present an excellent and complete *résumé* of those phases of the subject. Professor Dana develops his well-known conceptions of the relief of the earth as manifested in the continents and oceanic abysses, of the trend of mountain ranges and groups of islands. The pages on the classification and description of rocks impress us as not so good as are the other portions. A purely mineralogical system is carried out, and this leads to the association of some not very close relatives in the same group. For instance, under the "Potash-felspar and Mica Series" we find in order, granite, gneiss, mica schist, hydro-mica schist, or slate, agalmatolyte, paragonite schist, porcellanyte, trachyte, rhyolite and obsidian. Rocks so diverse in origin and so contrasted in texture ought not to be placed together. In carrying out consistently the mineralogical principle some greater advantages of other arrangements are lost. The classification of rocks is no easy matter, and there is all too little agreement about it among geologists; but, nevertheless, the broader principles of origin can hardly be ignored to advantage in descriptions.

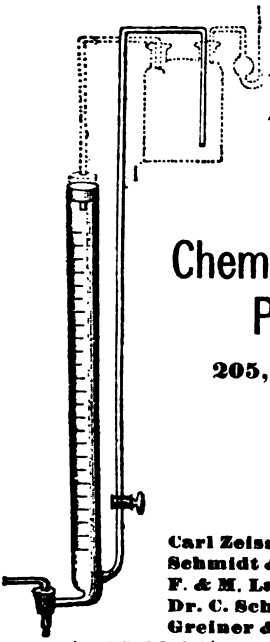
Under the subjects that relate to dynamical geology recent work has added vastly to our knowledge. The work of water has been so carefully studied, the questions regarding ice-action have been so thoroughly discussed, and the obscure problems of mountain upheaval—of the condition of the earth's interior and of vulcanism—though still unsolved, are yet so much better appreciated that especially good materials are available for the elucidation of them all. Moreover, Professor Dana could summon up a world-wide experience wherewith to cast light upon the views of others and to illustrate his own.

The portion of the work devoted to historical geology is altogether

admirable. Some might prefer slight changes in the nomenclature, but the conception of the rôle of faunas in the determination of strata has been admirably grasped, and the illustrations have been very happily selected. With a good museum and with good study collections, a student can follow the work through and get an excellent acquaintance with the development of life on the earth, while the general reader will be able to see pass before his eye the stately procession of organisms from the oldest to the latest. As a handbook for the field geologist it cannot be too highly commended.

The proof has been, in general, read with great care, and seldom are errata to be detected. The following seem, however, to have escaped notice: page 56, thirty-first line, "5" should be "45;" page 304, fourth paragraph, should have "Eureka, Nev.," instead of "Leadville;" page 313, first line, fine print, "Permian," not "Peruvian;" page 317, next to last line, "G. W. Hawes," not "S. W.;" page 945, fourth line, fine print, "J. E. Todd," not "I. E."

The work will no doubt hold and enlarge the old place held by the earlier editions as our leading American text-book. J. F. K.



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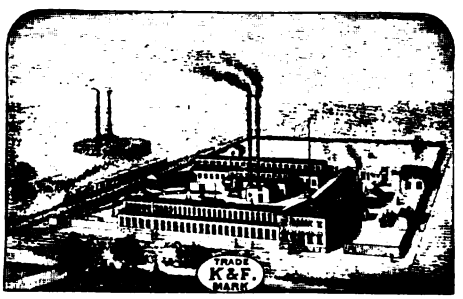

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VOL. XVI. JULY, 1895. No. 4.

SEGREGATION IN ORES AND MATTES.

BY DAVID H. BROWNE, SUDBURY, ONTARIO.

DURING the last few years, the origin of the Sudbury nickel-ore deposits has been the subject of much discussion. The igneous and the aqueous theories have been both strongly championed, and at the present date, while the balance of opinion leans to the igneous side, the lack of any decisive testimony on which arguments *pro and con* could be based, has tended to make a decision necessarily difficult and unsatisfactory.

Bell, in his report on the Sudbury ores,* says: "The general character of the deposits seems to indicate that they have originated primarily from a state of fusion." H. B. Von Fullon† states that "Die Erze sind nicht wässerigen, soudern feuer flüssigen Ursprunges," *i.e.*, "not of aqueous but of igneous origin." Vogt‡ assigns these and other similar sulphide ores to "segregation from a molten basic magma," and Kemp§ gives it as his opinion that the appearance of the ores "leaves no reasonable alternative but to conclude that they are as much an original crystallization from the igneous magma as any other mineral in the rock."

On the other hand, Posepny refers to the igneous theory as

* *Report on the Sudbury Mining District*, p. 49.

† *Ueber Einige Nickelerzvorkommen*, p. 281.

‡ *Zeitschrift für praktische Geologie*, Nos. 1, 4, 7, 1893.

§ *Ore-Deposits of the United States*, p. 319.

something extraordinary; Emmens* thinks that nickel is an essential constituent of the gangue, and Argall† "submits that it is to the leaching of basic eruptives at or near the surface our principal deposits of nickel are due."

All these latter opinions, based as they are on resemblance to other ore-deposits, may be considered as *obiter dicta*. To one familiar with the unique appearance of the Sudbury ores, their immense size, their geological and commercial importance would seem to warrant close study, long-continued observation and experimental research before a sound judgment as to their origin could be reached. In order to furnish some material or basis on which a judgment can be made, the following data concerning the similarity of segregation in mattes and ores are submitted:

Copper-nickel matte, made in water-jacketed blast-furnaces from roasted copper-nickel ore, consists of a mixture of sulphides of copper, nickel and iron. An average matte will contain, approximately,

Cu, 24 per cent.
Ni, 20 " "
Fe, 28 " "
S, 28 " "

This matte is tapped into hemispherical or conical cast-iron matte pots or moulds, in which it is allowed to set, after which it is turned out on the dump to cool. These moulds or matte pots are about 24 inches diameter by 14 inches deep. After the matte has set, and while cooling on the ground, it cracks by contraction, the cracks extending either radially from the centre, splitting the matte into pyramidal or cuneiform fragments, or else vertically through the centre, dividing the matte into quarter sections. On a pot of matte broken in the latter shape, concentric iridescent bands of color show the rate at which the matte has cooled from outside to centre. The specific gravity of matte does not vary appreciably throughout a pot, it being, as a rule, from 5 to 5.2.

After matte has been broken, two separate forms of incrustations may be observed on its surface. The first consists of small hairs or wiry crystals of copper, often occurring in small geodes or bubbles near the top or outside of the matte pot. The second

* *Canadian Mining and Mech. Rev*, August, 1893.
† *Nickel*, etc., Colorado Scientific Society, December, 1893.

consists of ferro-nickel crystals,* generally found near the centre or bottom, and having the form of squares or rectangular triangles about $\frac{1}{8}$ to $\frac{1}{16}$ inch in diameter. These are tin white, very thin, flexible and highly magnetic, and have the formula Fe_8Ni_9. While comparatively rare, yet close examination will discover the presence of ferro-nickel in almost every pot of matte.

It has been known for several years that matte is not homogeneous throughout each casting, nor is it surprising that in such a fluid mixture of different sulphides the elements should, during the time of cooling, attempt to arrange themselves with regard to their respective affinities. A long series of experiments to determine what these tendencies were, may be thus briefly summarized.

Numerous analyses showed that in one and the same matte casting a sample broken from the top will be, as a rule, higher in copper and lower in nickel than a sample from the bottom. Eleven pots thus examined gave an average as follows:

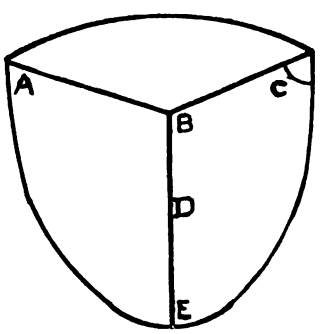
	Cu.	Ni.
11 top samples, ...	23.26	20.15
11 bottom samples, ...	21.14	20 32
	2.12	0 17

Gain Cu at top, 2.12 per cent.
" " bottom, .17 per cent.

The copper seems to vary more rapidly than the nickel from top to bottom.

Further analyses showed that nickel was higher at the centre than at the bottom of the casting. A few examples will illustrate this tendency. A pot casting broken into quarters was sampled at the points shown in the sketch, and analyzed as follows:

FIG. 1.



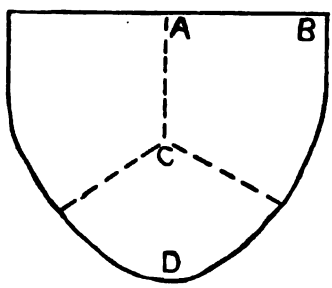
* *Jour. Anal. Chem.*, March, 1892.

	A.	B.	C.	D.	E.
Copper, . . .	25.00	25.62	25.02	20.80	24.46
Nickel, ...	20.2	20.9	20.5	21.60	20.20
Iron, ...	29.4	27.3	28.8	35.5	31.5

These analyses show that copper tends toward the top and outside of the casting, while nickel and iron tend to concentrate toward the centre.

A half pot was now selected in which radial cracks seemed to show the centre of segregation. Small portions were broken off at the points indicated and analyzed as follows:

FIG. 2.

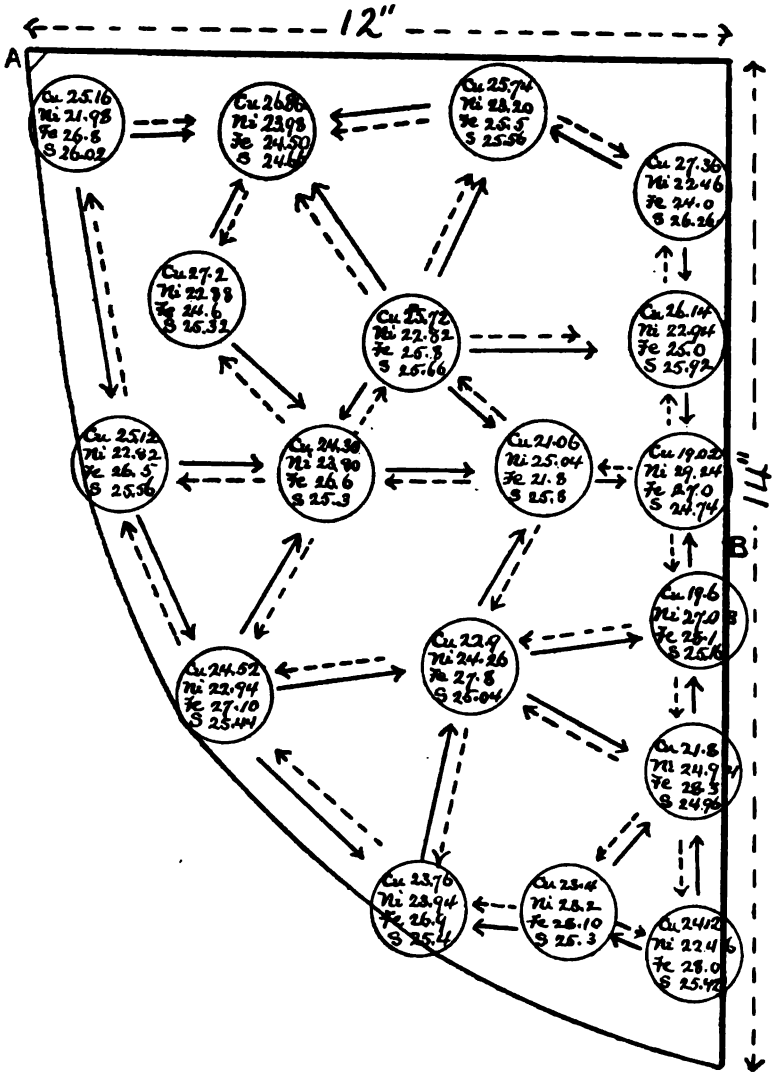


	A.	B.	C.	D.
Copper, ...	24.46	23.68	22.46	22.80
Nickel, ...	18.02	19.06	19.16	18.74
Iron, ...	31.0	31.5	31.5	32.00

These samples showed as before the upward and outward tendency of copper, but did not so clearly show the inward tendency of nickel. The reason was found to lie in the manner of sampling, as it was found almost impossible to break with a hammer the sample desired, at the exact point in question. In order to get a correct sample, and to map out, if possible, the variations of copper and nickel, a quarter pot was placed under a drill and sampled as indicated in the following sketch by drilling with an inch drill holes one-half inch deep at the points marked. These samples were then carefully analyzed, and as they were entirely free from slag, the sulphur was in each case taken as the difference between the sum of copper nickel and iron and 100 per cent. which has been found to be very nearly the correct amount.

The entire quarter pot was now crushed, quartered, sampled and analyzed.

FIG. 3.



Section of quarter pot a little over one-third natural size.

It contained

Cu, 24.64
Ni, 22.86
Fe, 26.70
S, 25.82

The pot is drawn to a scale of about ⅓ natural size. The analyses are for convenience written in their respective locations.

The specific gravity of matte at the point A, was 5.26 and at B was 5.2. The solid arrows in the sketch indicate the movement of nickel, while the dotted arrows show the movement of copper. Examining these lines carefully, it will be seen that the segregation of nickel to the centre and the dispersion of copper to the outside is very pronounced, variations in the percentage of these two ingredients to the amount of 7 per cent. occurring over a space of three or four inches. It will also be noticed that copper and nickel seem to be mutually antagonistic, an inward flow of nickel being almost always accompanied by an outflow of copper.

Taking the vertical central line and the horizontal central line, as showing the tendencies of the metals at their greatest fluidity we may now map the variations in a curve.

From the vertical central lines it will be seen that the curves of copper and nickel are nearly reciprocal. The horizontal central line shows a similar tendency. From these examples, which are given merely as an illustration of what has been proved true by numerous other analyses the following statements may be inferred:

1. In a mass of molten copper-nickel iron matte, the sulphides of copper and nickel are mutually antagonistic.

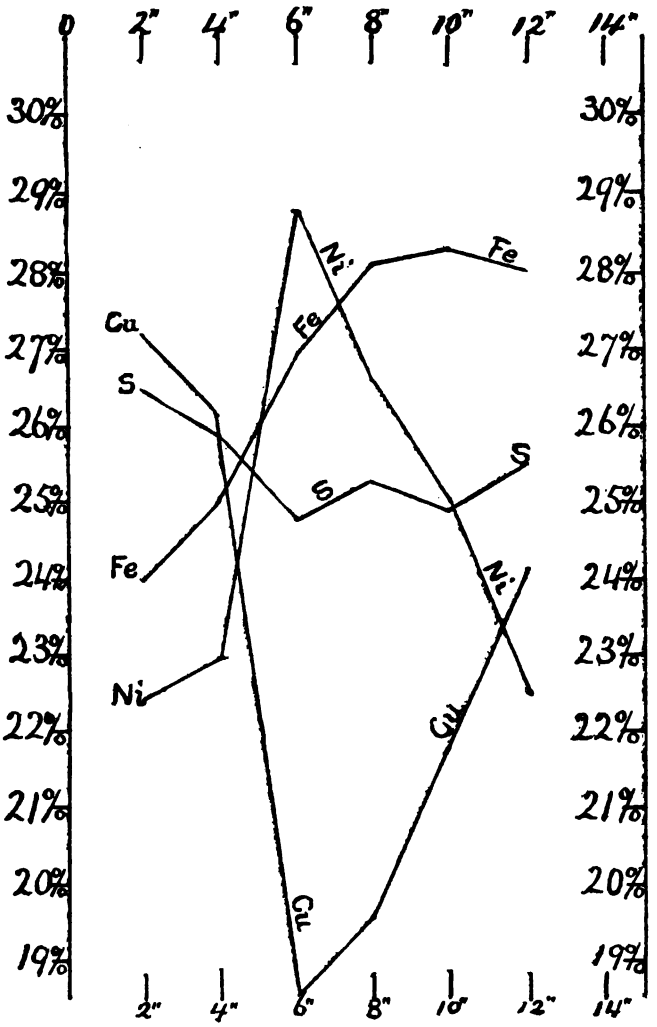
2. The tendency of nickel and, though in less degree, that of iron is also to concentrate toward the centre, with a slight downward inclination.

3. The tendency of copper is to disperse toward the outside and to rise toward the top of the casting.

These statements are verified in a striking manner by furnace practice. The matte as it flows from the blast-furnace passes first to a forehearth in which it accumulates and the slag rising to the surface is separated. In this forehearth, where the matte is subjected to a prolonged heat, nickel tends to sink to the bottom, and as after every tapping there remains a layer of matte perhaps two or three inches thick in the forehearth below the tapping ring, this matte becomes gradually enriched in nickel and impoverished in copper. On changing the forehearth after several weeks running the bottom is found coated with a tough magnetic matte which averages about 46 per cent. nickel and 12 per cent. copper. The matte made in this forehearth has during the run averaged

perhaps 22 per cent. copper and 18 to 20 per cent. nickel. This shows that under prolonged heating the copper nickel sulphides

FIG. 4.



Central vertical line of matte.
Vertical column = per cent. Horizontal column distance from top of pot.

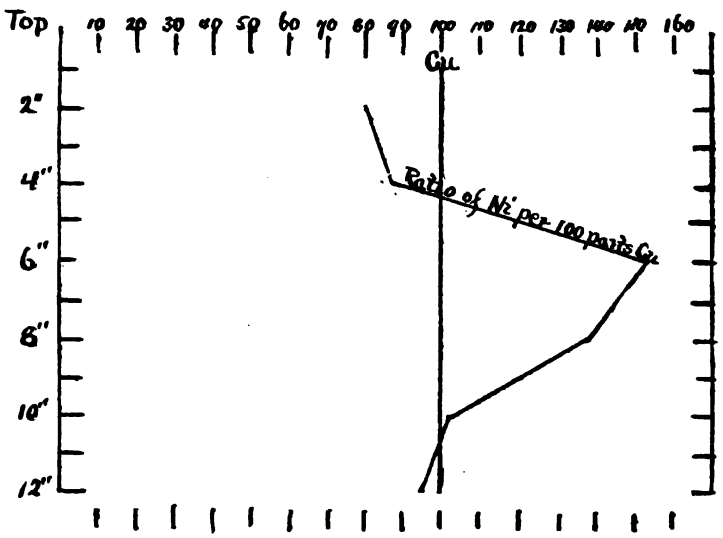
are more perfectly separated, the copper going upward and the nickel downward.

Again, the Orford process* of separating copper from nickel

* *Mineral Industry*, 1892, vol. i., p. 357.

consists in smelting matte with sodium sulphide produced by reduction of salt-cake with coal. The sodium sulphide forms with the matte an exceedingly fluid magma from which on cooling nickel separates as a "bottom" or cake of nickel sulphide occupying the lower part of the matte pot, while copper floats upward with the soda sulphide. After cooling a sharp demarcation line is found between the two sulphides, and by separating the "bottoms" or crude sulphide of nickel and repeatedly resmelting with sodium

FIG. 4A.



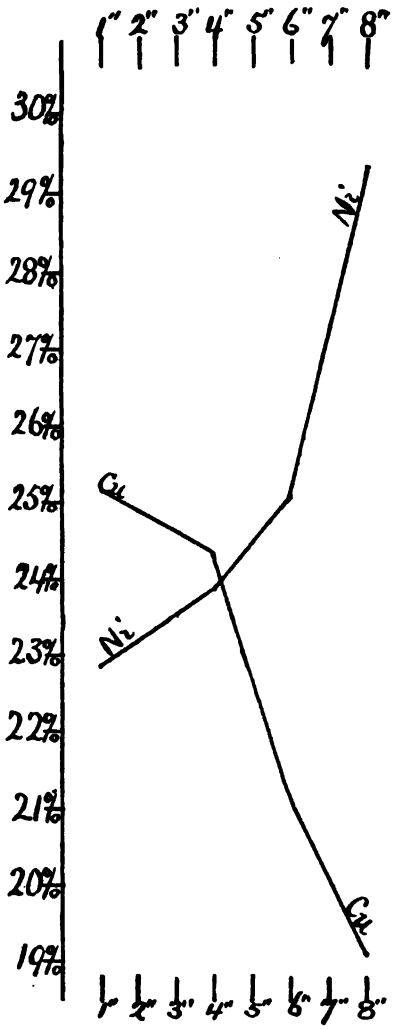
Central vertical line of matte.
The per cent. copper taken as 100.
Vertical lines distance from top. Horizontal = variation of nickel.

sulphide the copper can be almost entirely removed and pure sulphide of nickel can be produced. We are thus justified in drawing the following inference.

If copper-nickel-iron sulphides can be held in a molten condition either by using prolonged heat or by imparting fluidity by the addition of fluxes for a sufficient period of time to allow the mutual repulsion of the metals to act, the copper and nickel will separate as individual minerals, the sharpness of separation being dependent on the fluidity of the mass and the time occupied in cooling.

If we now examine the Sudbury ore-deposits, a general resemblance in their formation to the formation of mineral in mattes

FIG. 5.

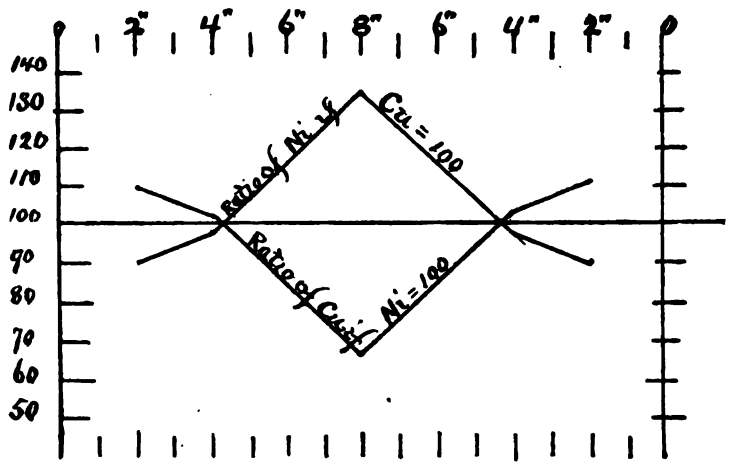


Central horizontal line of matte.
Vertical column = per cent. Horizontal column = distance from outside.

may be readily seen. The tendency of copper pyrites to separate from the nickeliferous pyrrhotite is very noticeable. However closely the two minerals may be intermingled, each is entirely

free from traces of the other. The chalcopyrite is free from nickel, while the pyrrhotite beside it is equally free from copper. Beside this chemical separation, there is an equally noticeable physical separation. Bell,* Kemp † and others have remarked the tendency of copper pyrites to separate in veins or stringers of ore surrounding masses of included diorite. It may be stated as a rule, that copper tends toward the rock, whether forming the vein-walls or forming included masses. The miners often remark the

FIG. 5A.



Central horizontal line of matte.

Horizontal distance = distance from outside to centre of pot. Vertical height = per cent. of metals.

way in which copper follows the rock, and look on the presence of massive copper-ore as indicating an approach to the rock. In driving a drift from the shaft which is sunk in the clean diorite to and through the ore, the first symptoms of the presence of the vein are small shots or pockets of copper pyrites impregnating the rock. Coming nearer to the ore-body, the amount of copper increases,‡ large masses being met with before any nickel is found. On reaching the ore-vein proper, the copper pyrites is found mixed with pyrrhotite and rock, while in the heart of the vein a large quantity of nearly pure pyrrhotite almost free from copper

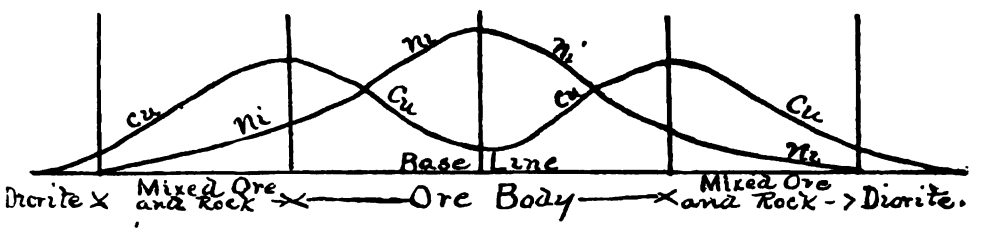
* *Report on Sudbury Mining District*, 1888–90, p. 49.

† *Ore-Deposits of the United States*, p. 319.

‡ Peters: *Modern Copper Smelting*, p. 291.

is found. The cross-section of the ore-body then shows as follows: rock, copper-ore and rock, copper-nickel ore, nickel ore, copper-nickel ore, copper ore and rock, and, finally, rock again. This can be mapped in the form of a curve across the ore-body in a horizontal line, the height of the curves showing the ratio of copper and nickel.

FIG. 6.



Horizontal Central Line of Ore-Body.

The above figure does not, of course, represent a cross-section of any particular mine, but shows, as well as can be done without figures, the manner in which copper and nickel are found on cross-cutting a large vein such as at the Copper Cliff mine. As there is much ore intermixed with the rocky walls, and many included fragments of rock in the ore-body itself, and as each mass of rock tends to attract copper-ore, it follows that the ore as mined shows about equal amounts of copper and nickel. Fig. 6 must then be taken merely as a general indication of the way in which the minerals occur at the Copper Cliff mine.

A general tendency of copper to disperse to the rock and to the vein walls, and of nickel to concentrate towards the centre of the deposit, is thus shown to exist in the ore-body. Comparing Fig. 6 with Fig. 5, it will be seen that in matte, as well as in ore, the travel of the metals is the same, copper moving outward along a horizontal line toward the cool outer surface, and nickel moving inward to the centre.

That copper-ore is attracted by the rock is readily seen on examining the rock heaps at the various mines. This rock occurs not only at the edges of the deposit, but also in masses of every shape and size in the ore-body. If the ratio of copper and nickel in the ore be taken as 1 to 1, *i.e.*, 100 pounds copper to every 100 pounds nickel, the ratio in the sorted rock will be from 150 to 200

pounds copper to every 100 pounds nickel. These metals are not an essential constituent of the rock, but occur as shots and veinlets of ore scattered through a dioritic matrix.

We are justified, then, in stating that in the ore-body the tendency of copper is outward along a horizontal line toward the rock, while the motion of nickel is inward toward the centre of the vein.

It has been often said that the Sudbury ore-deposits were originally worked for their copper contents, and that the presence of nickel was noticed only after deeper excavations had been made. This is in a certain sense true. The surface workings of the Copper Cliff mine, for example, yielded nearly pure copper pyrites, while the lower levels give nearly equal proportions of copper and nickel. The change is regular and gradual.* Business considerations forbid the use of comparative figures, but in general terms it may be said that a deposit which shows large amounts of copper and small amounts of nickel at the surface, changes regularly with the depth to a nearly equal ratio at the present time. The tendency of copper and nickel to separate—the copper outward and the nickel inward—seems also to increase with the depth. Taking the copper as unity, and plotting the percentage of nickel at each level as a factor thereof, the ratio of the two metals will be shown to approach each other as the depth increases.

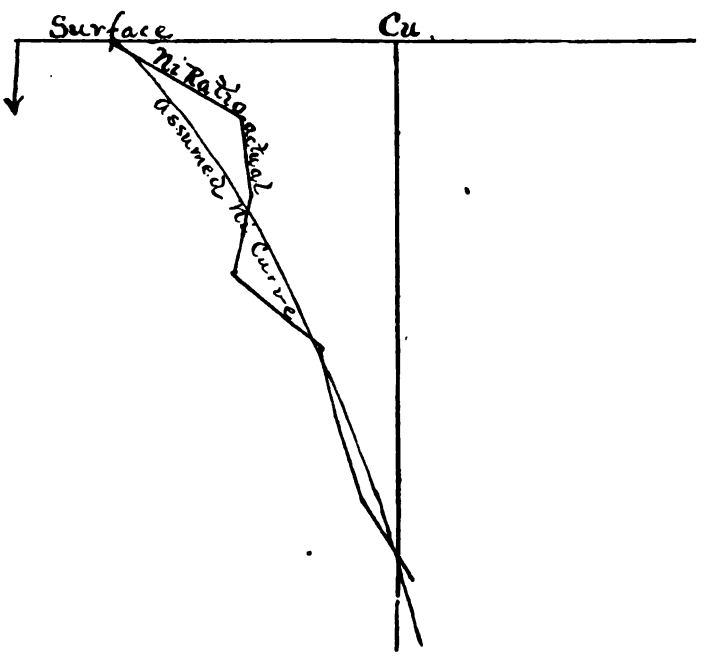
Comparing this Fig. 7 with Fig. 4 A, it will be seen that in the mattes the tendency is to change from a high copper matte at the surface to matte carrying nearly equal amounts of copper and nickel at about one-third the depth of the pot, then a rapid decrease of copper and increase of nickel near the centre, and a recovery to nearly equal parts of copper and nickel at the bottom. In the ore we cannot tell what proportion of the depth of the deposit has been opened out, but there is, nevertheless a parallelism between the ratio of copper and nickel in the ore as far as opened and the rato of copper and nickel in the upper half of the matte pot.

From the behavior of copper-nickel mattes kept for a long time in a molten condition, we have drawn the inference that in proportion as the time of cooling is prolonged, the more perfect is the separation of copper and nickel into their respective sulphides. If the theory of igneous origin be the correct explana-

* Levat: *Progres de la Metallurgie du Nickel*, p. 27.

tion of the Sudbury ore-bodies, it is evident that the upper and outer portions of the deposit were the first to cool, while in the centre and lower part of the deposit the sulphides have longer remained fluid. If, then, a parallelism exists between the ore and the matte, we would expect to find the separation of nickel more perfect on the lower levels than on the upper. This is in reality

FIG. 7.



Vertical central line of ores.

Ratio of nickel to copper in ores. Vertical line = copper taken as unity. Heavy line = ratio of nickel. Light line shows average variation of nickel ratio. Vertical distance shows depth from surface.

the case. The nickel-bearing portion of the Sudbury ores consists of magnetic pyrrhotite containing more or less intermixed pentlandite. Nickel may be considered to exist in the pyrrhotite as a foreign element, replacing a certain portion of the iron. Pentlandite, on the other hand, is a true nickel mineral (Fe+Ni), S, containing approximately Ni 35 per cent., Fe 30.25, S 34.75. While it is true that the percentage of nickel in the picked nickel ore does not vary much with the depth, yet the deeper the mine, the

more perfect will be the separation of nickel as a true nickel mineral. This nickel mineral does not occur in separate massive form, but as small crystals or patches, varying in size from that of a pin's head to a hazel nut, intimately associated with the pyrrhotite. By crushing to a rather coarse powder and sorting with a magnet, the minerals can be separated for analysis.

In ore from near the surface the crystals of pyrrhotite are small-grained, bright and sharply lustrous, containing more than one-half of the total nickel as an element replacing iron; while in ore from a depth of several hundred feet the pyrrhotite is largely in soft, dull crystals containing very little nickel as an element replacing iron. The following analyses will show this tendency:

Copper Cliff Mine.	Depth in feet.	Per cent. of Total Ni in Pyrrhotite.	Per cent. of Total Ni in Pentlandite.
	Surface.		
Picked Ni ore.....	.....	51.7	48.3
" "	600	34.	66.
" "	700	29.	71.
" "	800	18.	82.

In samples of ore of the same percentage in nickel, taken from different depths in the deposit, the nickel separates as an individual mineral more perfectly as the depth increases, or, in other words, at those points in the deposit where, if the igneous theory be true, the ore has remained longest in the molten condition, and better opportunity has been offered for physical and chemical separation.

We have now seen that an agreement in the method of arrangement of the elements exists between the ores and mattes along the following lines:

1. The tendency of copper in both ores and mattes is to rise vertically upward and accumulate at the surface, and also,

2. To travel horizontally outward from the centre and accumulate on the outer cooling surfaces.

3. The tendency of nickel in both ores and mattes is to sink vertically toward the centre, and also,

4. To leave the outer cooling surfaces and to travel horizontally inward toward the centre.

5. In both ores and mattes the separation of nickel in the lower part of the deposits as an individual mineral sulphide is in direct

proportion to the fluidity of the mass and the length of time occupied in cooling.

It does not seem possible to explain this parallelism by any other theory than this; that the nickel deposits of Sudbury existed primarily as eruptions of molten sulphides mixed with the constituents of the dioritic enclosures, and that by gradual cooling the diorite was first separated, then the copper as copper pyrites, and the iron as pyrrhotite containing some nickel, and, finally, in those portions remaining longest molten the nickel separated as a true nickel mineral. While this view may be at variance with the theories of many authorities, yet it seems to be the only conclusion feasible in view of the similarity in the manner of segregation of the elements in copper-nickel ores and mattes.

APPENDED NOTE TO THE PAPER* OF MR. BROWNE.

By J. F. KEMP.

THAT the reactions of metallurgical processes have served to throw much light on the problems of igneous rocks has long been recognized, and from the observations of J. H. L. Vogt, and others, on slags and the artificial minerals yielded by them, important inferences have been drawn regarding rocks. This source of evidence is a fruitful and suggestive one, for, although on a small scale when compared with volcanic phenomena, the parallelism, so far as it goes, is close—the principal difference being that slags cool quickly, under slight pressure and without the presence of mineralizers. The advantages are that the reactions are under observation, and all the factors can be noted.

Late developments in the mining of associated nickel and copper ores, and attempts both recent and early to utilize titaniferous magnetites have exposed such geological relations, that many observers have felt compelled to regard the ores themselves as of igneous origin. They occur in rocks of this original character, and ores that show small evidence of any geological disturbance. In the case of the associated sulphides of nickel and copper, the

* This note is added with the full sanction of Mr. Browne.

occurrence of the ores in the outer portions of the intrusions has been the chief argument against their igneous origin, for they have been regarded as contact deposits, and have been referred by the writers cited above by Mr. Browne, to aqueous solutions.

But as our knowledge increases, of the changes that take place in those molten magmas that have remained in this condition some time before crystallizing, we have come to recognize that very important differentiations take place, and always with the relative increase of the basic minerals toward the outer portions. Alfred Harker has shown this for gabbros in England; Pirsson has done the same for syenitic rocks in central Montana, and G. P. Merrill for others in the southwestern portion of the same State. Many other observers have noted equally significant, though less extensive manifestations of similar phenomena. Instead of magmas being fairly homogeneous and stable, we must regard them as quite the reverse, and as subject to changes and differentiation, whose causes we perhaps do not yet fully understand.

It is not every magma that holds enough metallic elements to yield an ore-body; but where such are present with sulphur, it is reasonable to infer that the resulting sulphides would follow the course of the basic minerals. If the latter tend to segregate toward the contacts, so would the former. This is the line of argument that has been previously followed. Mr. Browne's paper now adds the further important point that even in small amounts of fused matter, and above all in those made still more fluid in the Orford process by the addition of sodium sulphide, the two metals, nickel and copper, tend to separate according to the relations that are observed on a large scale in ore-bodies.

While we do not fail to appreciate that it is a long step from a pot of fused matte to a great ore-body some hundreds of feet in extent, yet the parallelism is very significant, and it is fair to infer that what holds good for the small amount would be even more marked in the large.

HOW TRANSLATORY MOVEMENT MAY BE DERIVED FROM VIBRATORY MOVEMENT.

BY J. WOODBRIDGE DAVIS, PH.D.

1. CONSIDER a space traversed by a single set of undulations of a very simple character; that is, let the vibration conveyed through the medium be an oscillation in a straight line at right angles to the direction of transmission. Such undulations can be thrown through a cord, and a particle attached to the cord will perform the oscillation described. It will serve to fix our attention for the present to picture the waves sent through a cord rather than those which traverse an elastic ether. For convenience of description consider the oscillations whether in ether or in the cord to be vertical, and the line of propagation to be horizontal. Let C be the source of vibration, and let C also be a symbol to represent the pitch of the vibration. Let distances, velocities and accelerations from the source be positive; let distances, velocities and accelerations toward the source be negative. Positive acceleration corresponds to repulsion; negative acceleration corresponds to attraction. The distance from crest to consecutive crest of the waves is the wave-length; the velocity of propagation divided by the wave-length is the rate of vibration, or the pitch. The extreme elevation of the crest above the hollow of a wave is the amplitude. All points of those portions of the wave which incline upward toward the source are moving upward; all points of those portions which incline downward toward the source are moving downward; all points of those portions which neither incline upward nor incline downward toward the source, namely, the summits of crests and bottoms of hollows, have for an instant no motion. The vibrational velocity of a particle of the cord is a maximum midway between crest and bottom, and diminishes each way to zero, the velocity varying as the inclination of the cord varies where the particle is. Of two particles consecutively placed in length of the cord, the phase of vibration of that which is nearer the source is always a little in advance of the phase of vibration of the other. For convenience we shall adopt the nomenclature of the musical scale, employing the letters, *a*, *b*, *c*, *d*, *e*, *f*, *g*, to denominate vibrations

of successively higher pitch from *a* to *g*, and also to designate particles or molecules from which the vibrations respectively emanate.

2. Let *c* be a particle, not of the undulating medium, but independent, capable of vibrating in only one pitch, and that the pitch C, and possessing an energy of vibration of its own. Let the amplitude of *c* be equal to the amplitude of the undulations, and, moreover, let the phase of *c* be the same as the phase of the undulations, where *c* is. For convenience of illustration suppose *c* to be a ring encircling the cord, but free to slide along it. There is no

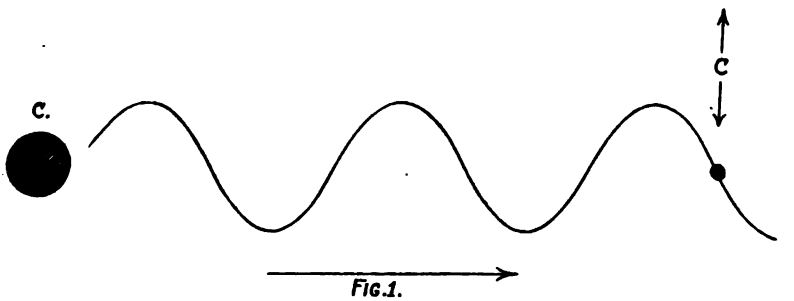


Fig. 1.

pressure at any time between *c* and the cord. Hence *c* acquires no vibrational energy from the undulations, and no motion of translation. Such motion is, indeed, resisted: for, if by extraneous force the particle should be urged toward the source, it would pass through more waves in the unit time, and therefore encounter vibrations of higher pitch than it is capable of assuming; motion of the particle from the source would likewise be resisted, as the particle would then encounter vibrations of lower pitch than it is capable of assuming.

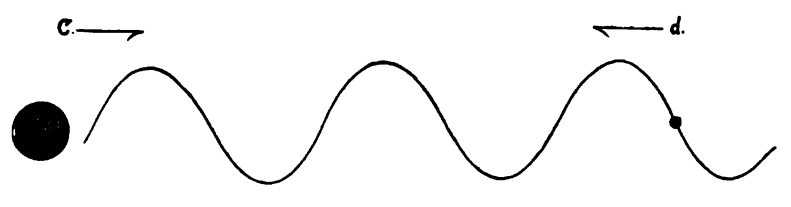


Fig. 2.

3. Substitute for the particle, *c*, a particle, *d*, whose rate of vibration is more rapid, or whose pitch is higher than C. Let the amplitudes of *d*, and of the undulations, C, be the same, and let

d start in the same phase with the undulations where *d* is. Then no pressure exists at the start between the ring *d* and the cord.

Since the particle *d* vibrates faster than C, or than any particle of the cord, it will be urged toward the source. For instance, if it start from the bottom of a hollow of the wave C, with a par-

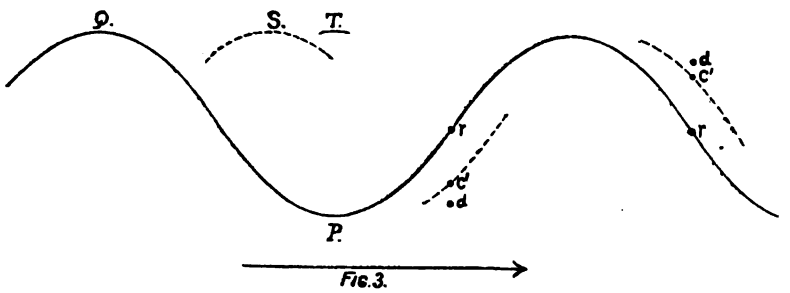


Fig. 3.

ticle, P, Fig. 3, of the cord, it will arrive at the crest, Q, of the wave before P will, namely, when Q will have reached the position S, while P will arrive at the crest when the latter will have rolled a half-wave length, Q T. The free particle will in the same way advance toward the source on the reverse stroke of the vibration. The action in detail is also illustrated in Fig. 3. If the ring start at *r* with the cord, it will, by its own rate of vibration, reach the position *d*, while the particle *r* of the cord is reaching the position *c'*, supposing neither meets interference. But, as the ring encircles the cord, it will be restrained from reaching the position *d*, and at the same time the cord will be carried beyond *c'*, so that the resultant mutual position of ring and cord will be between *d* and *c'*; that is, the cord will be deflected from the source, and its reaction will urge the ring toward the source, at the expense of a small portion of the energy of vibration of *d*, and also of the energy of vibration of the source.

4. In case of an elastic ether, consider a number of consecutive sections normal to the line of propagation, and of infinitesimal thickness in comparison with the wave-length. The phase of each section is always a little in advance of the phase of the adjoining section away from the source, and a little behind the phase of the next section toward the source. Let c_1, c_2, c_3, c_4, c_5 be five consecutive sections, c_1 nearest to, and c_5 farthest from, the source. Let the molecule *d* be in section c_3, and in the same phase as c_3. Since *d* is of higher pitch than C, it immediately reaches a more

advanced phase of vibration than c_3, that is, it corresponds with c_2 rather than with c_3, and still more than with c_4, and therefore finds less resistance to its vibration in c_2 than in c_3 or c_4. Suppose, for instance, that c_3 has reached the limit of its upward swing and is, for an instant, motionless; d is already moving downward; so is c_2; and c_4 is still moving upward. d finds a free way for its motion in c_2. In general, the line of ether particles that, if the ether were in quiescence, would be straight from the source, is by the shearing force in the ether inclined upward and downward as

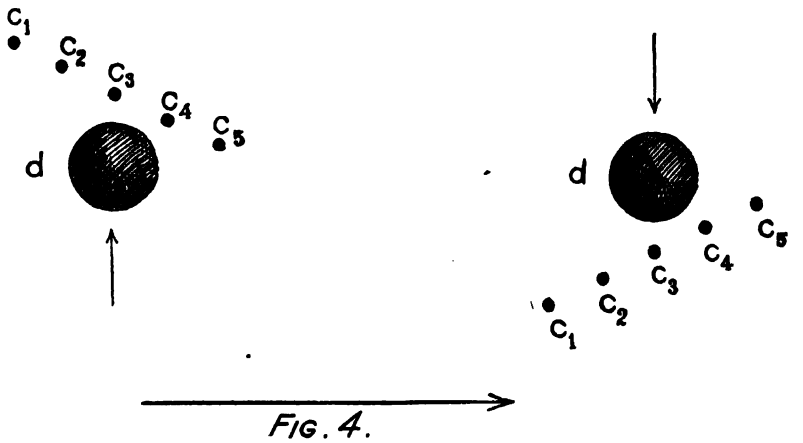


FIG. 4.

in Fig. 4, and, apparently, acts as the cord acts upon the ring, as a reflecting surface, deflecting d always toward the source. Whereas, the cord receives the entire deflection from the ring and returns the entire reaction, the molecule d probably breaks through numerous such strings of particles as c_1–c_5 in immediate succession, the effects of the encounters being cumulative, and of the same nature as the pressure engendered between rope and ring.

5. The attracting force that C exerts upon d varies not only according to a function of the intensity of the source and the distance between, but also as a diminishing function of the velocity of d toward C. So far as the latter factor is concerned, the acceleration is greatest at the beginning, when the dissonance between C and d is most. As the velocity of d increases, the dissonance and acceleration diminish toward zero as a limit, and the velocity approaches a limit easily found, as follows: c and d denote the numbers of vibrations per second of the source and molecule, V_d, the relative velocity of d with respect to C, and V, the velocity of

propagation; then, for unison to occur, or acceleration to cease, *d* must move toward C, *d*—*c* wave-lengths of C per second; but the wave-length of C is V ÷ *c*;

$$\therefore V_d = \frac{d-c}{c} \cdot V.$$

6. The source of vibrations, C, is, by the law of action and reaction, equally attracted toward *d*, as indicated by the small arrows in Fig. 2. From each pulsation *d* extracts a pull, and this pull must be supplied to each pulsation by the source. In case of the rope and ring, the urging of the ring toward the source through the distance, T S, Fig. 3, or the deflection of the rope from the source between *c'* and *d*, is felt all along the rope to the source as a pull. Hence, the limiting velocity exhibited above refers to the mutual approach of C and *d*.

7. In the case of two particles vibrating at the rates C and *d* of the natural gamut of musical notes, and with the undulations emanating from C with the velocity of sound, the limiting velocity of approach due to mutual attraction is ⅛ V = ⅛ of 1110 feet = 140 feet; it is the same for corresponding octaves of C and *d*. The limiting velocity for C and *e* is 240 feet, for C and *f*, it is ⅓ of 1110 = 370 feet. The limiting velocity of approach of a particle emiting undulations of the wave-frequency, A, of the light-spectrum, and a particle of wave-frequency, B, of the spectrum, the latter affected by the undulations of the former, is, when the velocity of propagation equals that of light,

$$\frac{7604 - 6867}{6867} \times 186{,}000 \text{ miles} = 20{,}000 \text{ miles per second.}$$

8. The limiting velocity, or velocity of unison, cannot be reached in finite time, however powerful the attracting force; neither is it likely to be approximated in any case. The attracting force is, however, likely to be very powerful in the case of vibrating molecules. If the amplitude of vibration of a molecule, affected by light of a certain wave-frequency, be only one-hundreth part of the wave-length, *l*, the velocity of vibration, at the instant when all the energy is kinetic, is $\frac{2\pi l}{T} \div \frac{100}{}$, while the velocity of propagation is $\frac{l}{T}$; that is, the velocity of vibration is six and a quarter

per centum of the velocity of propagation. From such an enormous store of vibrational energy—even when the amplitude is one-thousandth part of the wave-length—the energy required to impart to the same molecule, when its pitch differs from that of the undulations, a translatory velocity of 200 or 300 miles per second, would hardly be missed.

9. Substitute for the molecule, *d*, a molecule, *b*, whose rate of vibration is less than C. From a course of reasoning identical with the above, it follows that the pitch-difference between C and *b* causes a force of repulsion to arise between them, as indicated in Fig. 5, and that this force varies as a function of the intensity of

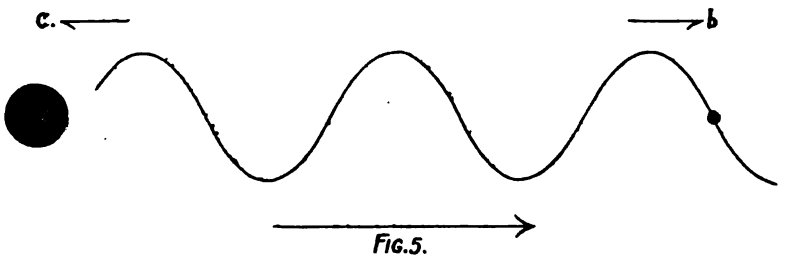


FIG. 5.

C, and the distance between C and *b*, and also as a diminishing function of the velocity of *b* from C. The limiting velocity, or velocity of unison, is the same as in the case of attraction, for the same difference of rates of vibration; but it is never reached.

10. Next consider the case in which the molecules, *b*, *c*, *d*, do not start in the same phase of vibration with the undulations of C. If *c* finds itself vibrating in exactly opposite phase from that of the undulations—which, however, is an unlikely and unstable condition—the undulations tend to reduce the amplitude of the molecule's vibration; but there is still no tendency to translation. If *c* is in any other phase of vibration with respect to the undulations, the latter urge the molecule to a position of unison. The cause of this movement is exactly the same as that of the translatory movements of *b* and *d*. When *c* is not in either of the states of equilibrium, stable and unstable, above described, it must be within a half wave-length of a position of stable equilibrium. Suppose it is ahead in its phase. It finds the section of ether next nearer the source more in correspondence with itself, and the section on the other side more resisting, than the section it for the instant occupies. A pictorial illustration can best be made of the

case of a cord and ring; c is the position the ring would occupy in the section $c\ c'$ according with the phase of its own vibration; c' is the position of the particle of the cord in the same section and according with the phase of the vibration of the cord. Neither will the cord allow the ring to occupy its natural position, nor will the ring allow the cord to occupy its natural position. A resultant mutual position, c'', will be taken: evidently the reaction of the cord drives the ring toward the source, except during brief intervals at the crests and hollows. If the molecule is behind in its phase it will be similarly urged from the source until it finds a position of equilibrium.

FIG. 6.

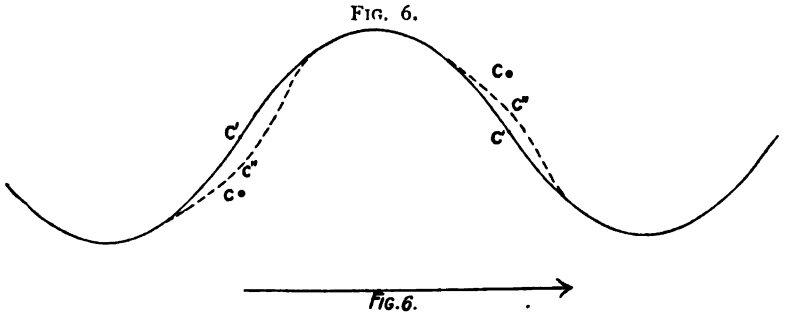


FIG. 6.

11. Inasmuch as the distance travelled cannot be more than half a wave-length, the movement just described is insignificant as a motion of translation, except when we consider distances between molecules less than half the length of the waves emitted. The motion is not absolute, but relative, the source of undulations and the molecule being mutually subject to the slight temporary repulsion or attraction. The action is exceedingly powerful for the brief period of its existence. If c start, as it will in the average case, a quarter vibration ahead of or behind C, then, even though it reach unison in a half vibration, as it is likely to do, the average tension between c and C during the half vibration is one-eighth of a vibration.

12. If b or d start not in the same phase with the section it occupies of the undulating medium, there will be instantly generated a powerful initial tendency to adjustment of phase, as in the case of c, by means of a minute movement toward or from the source. But this difference of phase and the consequent tendency to adjustment are incidental to the behavior of b and d even when these molecules start in the same phase with the medium. Until b and

d acquire a velocity nearly equal to V_d of ¶ 5, the difference of phase between them and the medium may take in succession all possible values, so that *b* and *d* may oscillate forth and back in the line of propagation, at the same time that *b* is repelled from the source and *d* is attracted, the oscillation decreasing as the velocity of translation increases.

13. If the molecule *b* be prevented from moving in the line of propagation otherwise than to swing forth and back through a minute interval of space, it will be caused to oscillate in the line of propagation; for, on account of its pitch-difference and its inability to reach unison through translatory motion, the phase of *b* will alternately be in advance of and behind the phase of the medium. The force of repulsion, however, will continue longer than the force of attraction and the molecule will struggle to move from the source of vibration. In the same way *d* will flutter back and forth in the line of propagation but will struggle to reach the source. The rate of this oscillation in the line of propagation is for *b*, *c–b*, and for *d*, *d–c*; the oscillations correspond to resultant difference tones in music, and give rise to special undulations in the medium.

14. If the molecule *d* be simply barred from approach to the source, while it is left entirely free to fly away, it will strike against the bar, its progress will be arrested, its phase of vibration will gain upon that of the medium until it will be more than a half vibration ahead, which is equivalent to being behind, the molecule will then fly from the source a little way until its phase of vibration reaches in advance again, then it will again strike the bar, and so continue to bombard the barrier at the rate, *d–c*. While *d* is moving from the source, being behind the medium in its phase, it gains in phase upon the medium, not only because its rate of vibration is more rapid, but because it moves into sections of the medium that lag more and more in phase; the tension slips away. When *d* moves toward the source, the tension is maintained by the motion. Hence, the molecule advances upon the barrier with velocity greater than that of its retreat. It follows that if the molecule, *d*, be permitted to move freely toward the source, it will upon striking the latter not remain in quiescent combination, but, finding the source a barrier, will, as just described, oscillate violently to and from the source. This motion is mutual; the source takes part in the new oscillation, and the compound, *Cd*, gains a kind of

vibration, of rate, *d–c*, peculiar to the compound, but lacking in each component.

15. Now let the molecules, *b*, *c*, *d*, be inclined to the line of propagation so that the vibrations representing their own energies do not take place in the direction of the vibrations of the undulations. The effect of the undulations upon the molecule, *c*, is to wheel it promptly into line with the vibration of the medium. This is shown graphically in Fig. 7. Let the vibrating ring, *r*, be in the

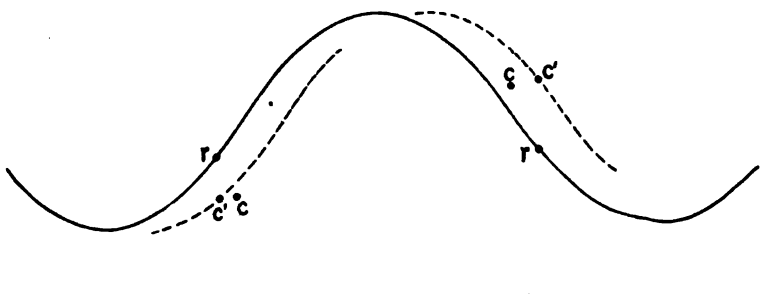


FIG. 7.

same phase with the cord at the point, *r*, where their lines of vibration intersect. At this point there is no tension between the vibrations. After a brief interval of time, the particle, *r*, of the cord will be moved to, *c'*, and the ring to the equally distant point, *c*, if no interference takes place. But since the ring encircles the cord, each will deflect the motion of the other, so that the position of the ring will be between *c* and *c'*; that is, the cord rotates the line of vibration of the ring until it becomes coincident with the line of vibration of the cord. The molecule reacts upon the source, so that a portion of the rotatory movement which tends to make the lines of vibration of source and molecule parallel, is performed by the source. This action is exceedingly powerful for the brief period of its existence, comparable with the energy of linear adjustment of vibrations already described. The effect of the two adjustments is to bring any vibrating molecule, *c*, into parallelism with the vibrations of the undulations and into unison with them.

16. The effect of the undulations upon an inclined molecule, *b* or *d*, is not to bring it into parallelism with the vibrations of the undulations, but to cause it to rotate back and forth, more or less violently, through an arc, whose middle radius is coincident with

the line of vibration of the undulations. The effect is the same upon a molecule whose initial vibration is parallel with the vibration of the undulations. Suppose the molecule to be initially vibrating in direction parallel with the vibrations of the undulations. Let $c'\ d$, Fig. 8, be the section in which d is vibrating, and let $c'\ d$, or $c_1'\ d_1$, be the difference in phase between d and the undulations, d being in advance. Let the molecule, d, be prevented from moving bodily toward or from the source, but let it be free to rotate about c'. When the cord should reach c', or c_1',

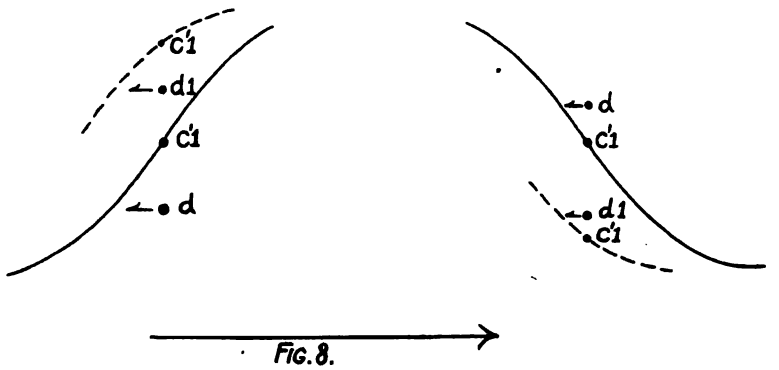


FIG. 8.

the ring should reach d, or d_1; hence, the ring is deflected toward the source. The result is evidently a rotatory oscillation of the line of vibration of d. When the lead of the molecule over the undulations is small, the rotatory oscillation is gentle; as the higher pitch of d increases the lead, the oscillation becomes more violent; when d has gained a half-vibration, the tendency is to completely overturn the molecule. Whether this latter tendency prevail or not, the line of vibration of the molecule is caused to perform continually an oscillatory rotatory movement of intermittent vigor in the plane of the undulations, and with the line through the molecule's centre parallel to the vibrations of the undulations as a median line. The rate of the oscillatory movement is c, and the interval between the instant when this rotatory oscillation is in greatest vigor and the instant when it is next so is equal to the time required for d to advance one complete vibration beyond C, and corresponds to the interval between consecutive beats in musical notes. If we consider d moving toward the source of undulations under the influence of the mutually attractive force due to their pitch-difference, the same effect is produced

upon *d*, since it can never come into unison with C, but the intervals between consecutive maxima of vigor become increased. The same effects are produced upon the molecule, *b*, as upon the molecule, *d*.

17. When *d* comes into collision with the source, the same rotatory oscillation continues. Because it is a relative movement, the source, C, partakes of it, oscillating in contrary sense, and the compound, *Cd*, acquires a kind of vibration peculiar to the compound and non-existent in the components.

18. The distinctive behaviors of the free vibrating molecules, *b*, *c*, *d*, immersed in the same field of undulations, C, *c* being isochronous with C, *d* of higher pitch, and *b* of lower pitch, than C, are briefly as follows:

c maintains a fixed distance from the source of undulations, and a fixed direction of its line of vibration, parallel to the line of vibration of C, and forcibly resists rotatory motion and translatory motion in direction of the line of propagation.

d moves toward, and *b* from, the source of undulations with a constantly increasing velocity that approaches a finite limit, and each forcibly performs a rotatory oscillation in the plane of undulations. When *d* reaches the source, it still maintains its rotatory oscillation, and it also oscillates to and from the source through a small space.

19. So far, the amplitudes of vibration of the molecules and undulations have been considered to be equal. This conception rendered the graphical and verbal demonstrations more simple. Let us now find the effect of a difference of amplitude. In figure 9 is shown the effect when the amplitude of vibration of the ring is less than that of the cord, their phases the same, and their periods isochronous. At *r*, the middle point of the vibrations, the ring and the corresponding particle *r* of the cord are coincident in position; no tension exists betwen them. A short time previously the ring was at c_1, the cord at c'_1; a short time after, the ring will be at *c*, and the cord at *c'*. The result is an oscillatory motion of rotation, more vigorous as the difference of amplitudes is more, and vanishing when the amplitudes of vibration of ring and cord become equalized. There is no motion of translation. If the amplitude of the molecule's vibration exceed that of the undulations, the same effects are produced. When we investigate the behavior of *b*, *c*, *d*, in any of the previously considered cases, with the am-

plitude of the molecule unequal to the amplitude of the undulations, we find that it simply consists of the effect of the difference of amplitude superposed upon the previously determined effects

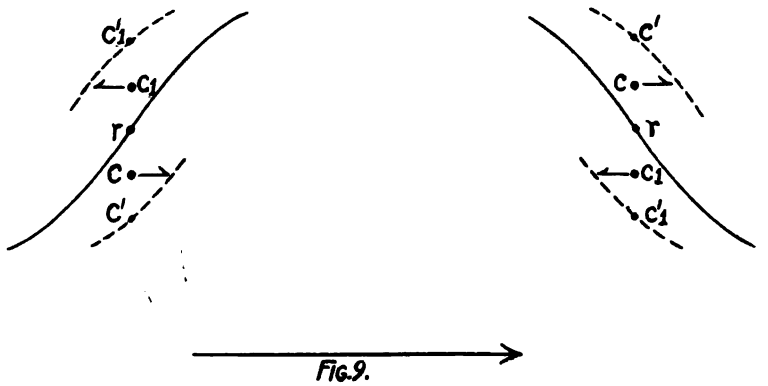


Fig. 9.

due to difference of phase and to pitch-difference. In the case illustrated in Fig. 1, *c*, if its amplitude be less than that of the undulations, will by the urging of the latter have its amplitude increased, and it will be caused to perform the rotatory oscillation illustrated in Fig. 9. As the amplitude of *c* approaches that of the undulations, the rotatory oscillation diminishes toward zero. The case illustrated in Fig. 3 appears as in Fig. 10, when the amplitude of *d* is less than the amplitude of the undulations. When the particle *r* of the cord reaches *c'*, the ring *r* reaches *d*;

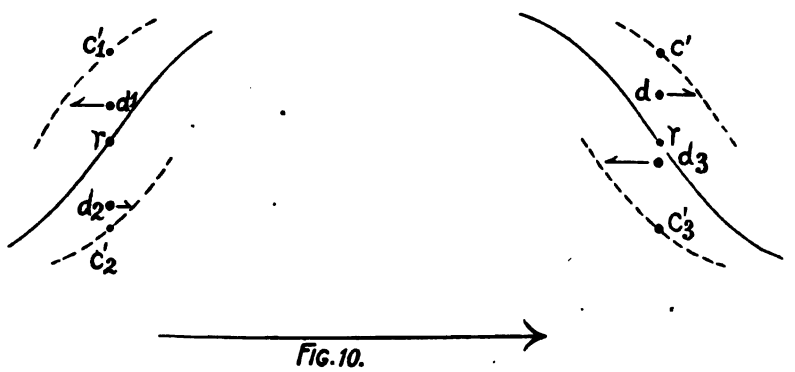


Fig. 10.

d is urged from the source. When on the return stroke the particle of the cord reaches c'_1, equally far from the middle point of vibrations as *c'* is, *d*, on account of its more rapid vibration,

reaches d_1, nearer to the middle of vibrations; d is urged toward the source, but with greater tension between itself and the cord than when it was on the upstroke. The resultant tendency is a movement of d toward the source, as illustrated in Fig. 3, and a rotatory oscillating movement such as is illustrated in Fig. 9. The resultant tendency during the remainder of the vibration is the same. The tendencies to translatory motion and to oscillatory motion of rotation are independent of each other, each depending separately for its magnitudeupon the amplitude of the vibration of d, the amplitude of C being considered fixed. The new construction for each of the other cases previously discussed shows likewise that the effect of a difference of amplitude is merely superposed upon the effects already deduced.

20. The only important modification that a difference of amplitude produces in the behavior of b, c, d, is that c, when of different amplitude from the undulations, does not tend to hold a fixed direction of its line of vibration parallel to the line of vibration of C, but tends toward a rotatory oscillation as in the case of b and d. The behavior of b and d is not materially changed by difference of amplitude from the undulations.

21. All the conclusions so far reached upon the hypothesis that

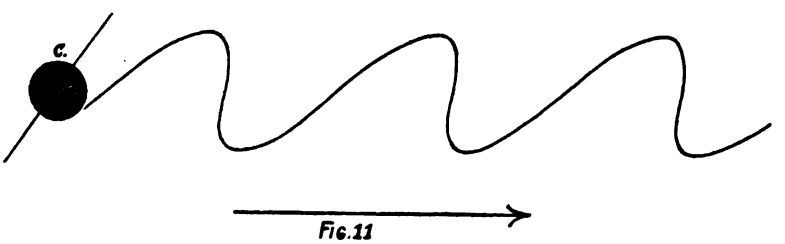


Fig. 11

the direction of vibration in the medium is normal to the direction of propagation, remain the same when the direction of vibration is inclined at any angle to the line of propagation. The graphical and verbal demonstrations remain exactly the same. In the limiting case when the line of vibration is coincident with the line of propagation, the undulations become like those of sound. Fig. 11 illustrates a case of inclined vibrations.

22. In the foregoing discussion, what is called the source of undulations is considered to be far more energetic than the molecules affected by the undulations, as is indicated by the use of a

capital letter, or, in the diagrams, of a large globe, to represent the source, while small letters, or, in the diagrams, points, represent the recipient molecules. The latter are likewise sources of undulations that affect C according to the laws by which C affects them, and the results are often counteracting. For instance, the undulations emitted by *d* cause a force of repulsion to arise between C and *d*, whereas the undulations of C engender a force of attraction; but, C being the more powerful, the net result is as described in ¶ 6.

In a future paper the writer will attempt to discuss the general case of the behavior of two molecules whose energies are represented by vibrations of any degree of complexity, resolvable, however, into the simple vibrations already treated, the two vibrations being like or unlike in some or all of their components, having the same or any different pitch, and equal or unequal energies. The behavior of *c* with respect to C, set forth in ¶ 18, indicates that an aggregate of molecules identical in nature will, by the coaction of the combined fields of undulations, have impressed upon it properties analogous to cohesion, elasticity and crystallization. The behaviors of *b* and *d* with respect to C, ¶ 18, may, when the general case is discussed, appear as a possible cause of the phenomena of capillarity and chemical affinity.

NOTE.—Two centuries ago Dr. Robert Hooke, probably in quest of the cause of gravitation, discovered that light articles, floating in an agitated body of water, were urged by the waves toward the centre of disturbance. (Dr. Robert Hooke's *Posthumous Works*, edited by R. Waller, pp. XIV. and 184) During the present century, Guyot, Schellbach, and Guthrie, severally experimenting with tuning-forks, found that these, when vibrating, attracted pieces of paper and other light objects; repelling, however, bodies lighter than the air, as hydrogen balloons. (*Lon., Edin. and Dublin Phil. Mag.*, June, 1871. The same number contains observations by Sir William Thomson, and the April number of the same year has a discussion of the subject by Prof. Challis) On page 246 of Ganot's *Physics*, 1883, is an interesting description of the behavior toward vibrating tuning-forks of balloons containing various gases, of candle and gas flames, of pieces of cardboard, which, when fixed, attract the freely suspended forks, and of diminutive mills whose arms carry resonators. In summing up, Ganot remarks: "These phenomena do not seem to be due to the aspirating action of currents of air, nor are they caused by any heating effect; and it must be confessed that the phenomena require further elucidation."

DETAILS OF MODERN WATER WORKS CONSTRUCTION.*

By WOLCOTT C. FOSTER.

PART IV.—PIPE-LAYING; CUTTING-OFF MACHINES; BRANCH-TAPPING MACHINES; LEAD; YARN; RECORDS.

THE pipe, valves, valve-boxes, hydrants and special castings are usually purchased, delivered f. o. b. cars at the railroad station nearest to the work. As a rule, the contract calls for the pipe-laying contractor to then take charge of them, and from the time of their arrival they are at his risk. The valves, valve-boxes, hydrants and small special castings should be stored in some safe place until needed for use on the work, so that they cannot be stolen or injured. The pipe and special castings are usually hauled direct to and distributed along the line of the work as rapidly as unloaded. Where it can be done, the pipe should be unloaded direct from the cars and placed upon the wagons, thus saving re-handling. It is well to distribute the pipe along in the gutter on the side of the street in which it is to be laid. This saves lifting it over a bank of fresh earth, and saves much time in cleaning out the gravel and dirt which may get into it. Before lowering into the trench, all foreign material should be removed from each length of pipe. For the smaller size pipes, it will be found very convenient to provide a light pole, about 14 feet long, and wrap around it old bagging and yarn to about the diameter of the pipe. This swab is pushed through each length, and clears out all foreign matter. After sufficient pipe is distributed to allow pipe-laying to proceed continuously, a gang of men is set to work at trenching. The dirt, where it is possible to do so, should be thrown upon the outside of the trench; that is, the side toward the centre of the street. This forms a barrier, and prevents horses and wagons being driven into the trench. A four-legged, light derrick will be found very convenient for removing boulders as well as for lowering the larger sizes of pipe into the trench. Where rock requiring blasting is met, the blasts should be light and well

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covered if the work is near buildings or any place where flying stones will do any harm. By properly covering the blasts, there is no necessity of having any of the stone thrown out of the trench. Under the body of the pipe, rock should be taken out from 4 to 6 inches or more below the grade, and the trench filled up to grade with earth and well tamped. At bells, the rock should be removed to such a depth as will readily allow of the joint being properly calked.

Immediately following the trenching gang comes the pipe-laying gang and calkers. The size of this gang depends upon the size of the pipe. First, the bell holes are dug, and these should be amply large enough to allow free swing to the calker's hammer. A length of pipe is then rolled over to the trench and cleaned out, after which it is lowered into place, the spigot placed within the bell of the preceding length, and the pipe forced home by means of a bar. The yarner then places the yarn in the joint, and forces it home with the yarning tool, Fig. 67. The joint is

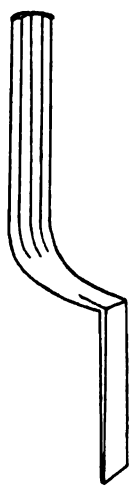


FIG. 67.—Yarning Tool.

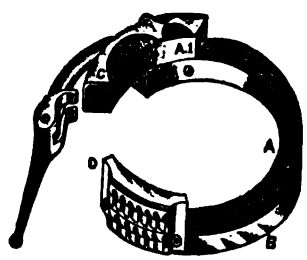


FIG. 68.—Jointer.

then ready for the lead. A "roll" is wrapped about the joint, pressed well up against the face of the bell, and the ends brought together on top of the joint, crossed and turned out to form an opening into which to pour the lead. The "roll" is made by taking some well-tempered fire-clay and making it into a long sausage-shaped roll, about 1½ inches diameter, around a strand of yarn. The fire-clay must not be either too wet or too dry, and

must be of even consistency and free from hard lumps. After one or two pourings, the "roll" should be worked by a boy and kept in good condition. For this purpose, a pail of water and a piece of board, about 4 feet long, will be needed. When the "roll" is not in use, it should be kept covered by a damp cloth. In place of a "roll," one of the patent jointers, Fig. 68, may be used. For pipe 8 inches in diameter or over, these will be found cleaner, quicker, more economical, and to leave a better and more even lead face. They are made of an elastic material, protected on the outside by a thin metal band. When the joint is a wet one, a lump of lard, placed in the gate or opening through which the lead is poured, will be found to prevent spattering and blowing out. Each joint should be made by one pouring. In pouring the lead, the man should stand back of the bell, so as to be out of danger in case of the lead being blown out. The lead furnace should be kept close to the work, and is preferably mounted on wheels. Very thin sheet-iron furnaces soon wear out or become damaged. For heating the lead-pot coke is the best material to use. The lead should be kept at an even temperature, but not heated red-hot. When the lead is at the proper temperature, it can be told by skimming the surface. When it is right, colors will form on the bright metal quite rapidly. At too high a temperature they will form instantly, and the surface soon become covered with oxide, causing a loss of metal. If the temperature is too low, the lead will chill in the joint and will not fill it. The lead-pot should be kept free from foreign material, such as coke, stones, oxide, etc., and especially is this true of the ladle. Shortly after pouring the joint, almost immediately, in fact, the roll or jointer can be removed. Care must be taken that there is plenty of yarn in the joint, and that it is well rammed in, otherwise the lead will run into the interior of the pipe, an undesirable event. Care must also be taken to see that no yarn extends out into the lead space, as it will tend to cause a leak.

After the joint is "run" and the "roll" or jointer removed, the calker first cuts off the piece of lead at the "gate" with a cold-chisel and also any excess of lead, all of which should be carefully collected and returned to the lead-pot. He then follows around the pipe with a cold-chisel loosening the lead therefrom to a slight depth. After this is done, he begins calking the lead up, using the tool shown in Fig. 69. There are usually three of these

tools each of a different thickness of nose. He commences with the thinnest, follows with the intermediate, and finishes with the thickest. After a joint is calked the lead should present a clean, smooth surface comparatively free from tool marks. The hammer used in calking is a short handled hammer, as shown in Fig. 70. In calking the joints the calker should have full and free swing for his hammer all around the joint and the blows should be strong and steady, though not heavy enough to crack either the pipe or the bell. It is preferable to have the entire operation of pipe laying and joint making watched by a competent, reliable and experienced man, especially the joint making, as much depends upon tight joints. The loss of water from a leaking joint is large in it-

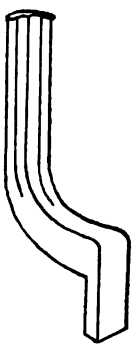


FIG. 69.—Calking Tool.

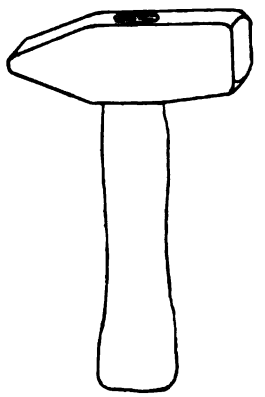


FIG. 70.—Calking Hammer.

self and may, besides, cause much annoyance and damage. The writer knows of an instance, which occurred in his own experience, in which a competent inspector was not placed over the pipe-layers by a previous engineer. The whole upper half of a joint was left out in laying a line of pipe. This joint was close to a culvert, through which, in wet weather, a stream ran, crossing the grounds of a very handsome residence. The pressure in the pipe line was about 150 pounds and after the water was turned on the brook became constant. It was a very nice thing for the person owning the residence but not for the town, as in a few years the town had to get an additional supply at a cost of about $60,000. Things eventually became so bad from this and other leaks that the pumps had to be kept running constantly all day and far into the night. The writer was asked to report upon the system and

in his examination discovered the leaks. After they were stopped, a few hours pumping each morning furnished all the water needed.

For cutting cast-iron pipe to odd lengths, a couple of light striking hammers and a few long handled chisels such as blacksmiths use, will be found very convenient. A line is first made around the pipe at the place where it is to be cut, either with a cold-chisel or a diamond-point tool and a hand hammer. This is followed by the long handled chisels, using the striking hammers.

The pipe is turned as the cutting proceeds and the pipe followed around with them until it breaks. Of late years a special cutting-off machine, Fig. 71 has been invented and come into more or less general use.

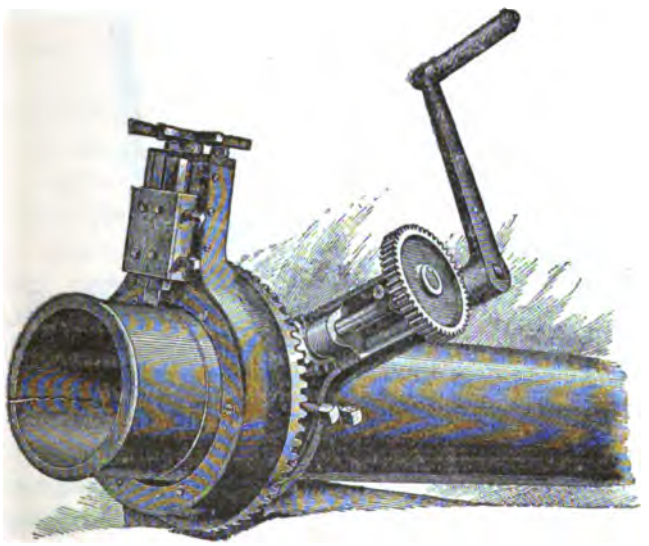


FIG. 71.—Pipe Cutting Machine.

For removing old pipe from a trench where it is desirable to save the pipe for use elsewhere, it will be found most convenient to melt out the joints. This is done by excavating a fair sized hole about and beneath the bell and building a wood fire in it. It is, of course, most economical to have as much of the fire as possible below the pipe. It will be found to facilitate matters and to save considerable fuel to have a sheet-iron drum made, with slots cut in it, so that it may set over the pipe and have the bottom rest upon three or four bricks placed in the trench. The rapidity with which a joint may be melted out when the fire is properly arranged

is surprising. The pipe should of course be thoroughly emptied of water. A boy can attend to the burning out of a number of joints at once. After the pipe is removed, the lead should be collected from beneath where the bells were.

For connecting new lines of pipe with an old one, where provision has not been made for such an emergency in the first construction of the work, by inserting a plugged special, there are several methods open. A special may be cut in or a "cutting in" special may be used; or a connection may be made by a hat flange as described in Part I. of this series of Articles. Or a branch tapping machine, Fig. 72, may be used and the connection made

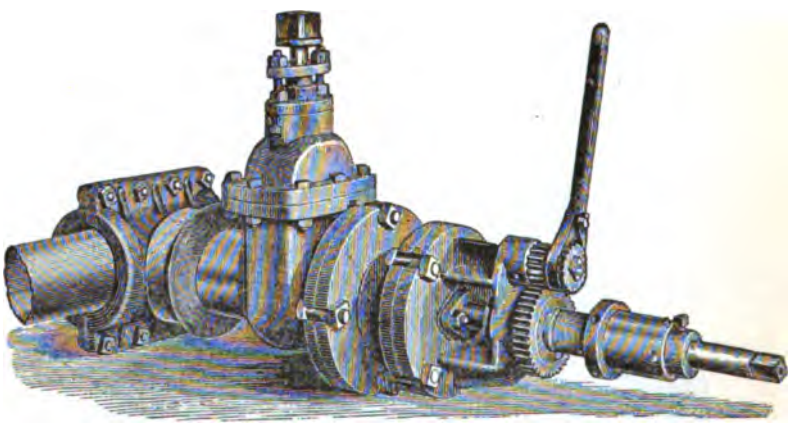


FIG. 72.—Branch Tapping Machine.

under pressure. These tapping machines come as large as to be capable of making a 48-inch connection with a 48-inch pipe. A bolted tee is first attached to the main to be tapped and the joints made up. A valve is then attached to the tee and opened. After bolting the tapping machine to the valve the machine is worked and as soon as the pieces are cut out of the pipe the cutting tool carrying the cut-out disk backed out and the valve closed. The tapping machine is then removed and the work is ready for connecting the new line.

Whenever work is suspended, the free end of the pipe should be stopped up with a wooden plug so as to prevent the small boy from filling the pipe with stones and other rubbish. When this precaution is not taken, one is sure to find the pipe full of undesirable material.

For handling the smaller sizes of pipe, carrying sticks will be found very convenient. A stick, such as an old pick handle, is run into each end of the pipe and the men can catch hold of these sticks to carry the pipe.

Following the calkers comes the back-filling gang. It is the business of this gang to fill up the trench and clean up the street. In back-filling the earth should be well tamped around the pipe and for about a foot above it. If in a much travelled street the tamping should be continued to the top of the trench. Along country roads it is frequently customary to fill the trench up by merely shovelling the earth in loose above the first tamping about the pipe and pile the excess over the trench, allowing the rains to settle the back-filling. In such a case a percentage of the payment is held back and the contractor either returns later on and finishes up, or it is done at his expense.

In back-filling, care should be exercised to prevent any large stones, or many stones of a smaller size, being put back in the trench. All broken rock and stones should be laid to one side and removed, and the filling done with clear earth free from them. When a road or street has been improved by being paved, macadamized or otherwise, the material forming the improvement should be kept separate from the earth excavated from the trench, so that it can be replaced. Where water can be obtained in sufficient quantity, it will be found to materially aid in settling the back-filling.

Where the water can be admitted to the pipe, and full pressure put on as the pipe is laid, it will sometimes be found advisable, especially with the smaller sizes of pipe, to test the work of each day before it is covered up. Fig. 73 shows an arrangement designed and used by the writer for doing this. The dimensions given in the cut are for 4 inch pipe.

A wrought-iron collar (A) is bolted about the pipe immediately back of the bell or spigot. The long bolts (B) are then run through the collar, and the cover (C) placed against the end of the pipe with a thick piece (about ¾ inch) of soft rubber placed between the cover and the end of the pipe. The nuts on the long bolts are then screwed up hard to form a water-tight joint. A piece of pipe, having a globe-valve on the outer end, is tapped through the cover on a level with the top of the inside of the pipes to allow the escape of air. The pipe line is filled with water,

the globe-valve is closed, and the pressure put on. An inspector then examines each joint, and marks any leaky ones which may be found with white lead or some other suitable material. The next day a calker goes over the leaky joints, and the trench is then ready for back-filling. Of course, the testing is done after the men have quit for the night, so as not to interfere with the work. On removing the testing apparatus, the water is allowed to escape into the trench. In most cases, this will do no harm, and it will be found that the water has entirely disappeared in a few hours.

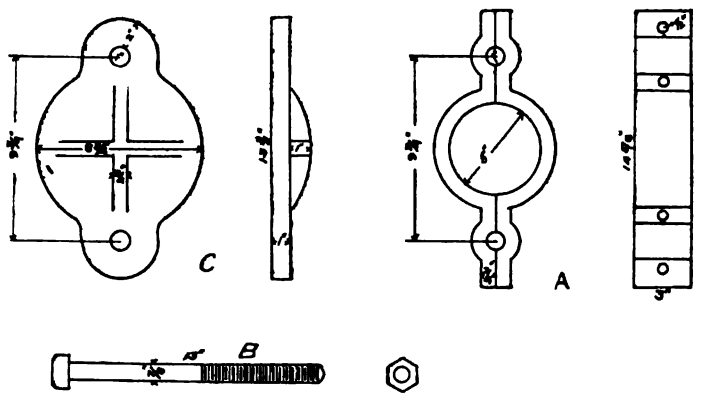


FIG. 73.—Temporary Pipe Cap.

If the joints are not tested until after the work is completed, very bad leaks will usually come to the surface, if not at once, in a short time. In some soils, however, this will not happen. Leaks can then be located by finding the position of a bell, and if whole lengths of pipe have been used, measuring off 12 feet each time, and sinking a crow-bar down to the level of the pipe. If the trench was a dry one, and the bar comes up muddy or wet, and especially if the mud is very soft and running, the chances are, that there is a leak at that bell. A little experience will enable a person to readily decide whether there is a leak or not by the appearance of the bar. Care should be exercised in sinking the bar not to injure the pipe. Rather than force it down with the aid of striking hammers, it is preferable to sink it by working it about or wriggling it.

In making joints, the bell should not be filled to its full depth with lead. It is not advisable to have less than 2 inches of lead

in the bell, though some engineers advocate less for the smaller sizes of pipe. The saving of lead in a less depth than 2 inches is small compared witn the annoyance that usually follows. For very large pipe, a greater depth is usual. A greater saving of lead per joint, without any annoyance, can be made by having the lead in the bell of moderate dimensions, and the thickness of the lead reasonable, than by attempting to reduce its depth. The amount of lead required to make a joint varies so much, depending so largely on the design of the bell, that it is impossible to give an amount which will answer in all cases. The following table, Table VI., gives several quantities, the results of experience with pipes of different makes and different designs of bells.

TABLE VI.—*Lead Required in Pounds per Joint.*

	Boston.*	Southern City.†	Fanning.	M. J. Drummond's Catalogue.	Fitzgerald.
4	8.4	.....	4.25	8.0	10.0
6	12 0	7.5	6.25	12.0	13.0
8	16.2	10.06	8.25	15 0	16.0
10	20.0	10.5	10.25	18.0	18 0
12	24.0	14.0	13 0	20.0	22.0
14	.....	.....	15.0	25.0	25 0
16	32.4	.....	24.25	30.0	29.0
18	.....	.....	27.25	35.0	33.0
20	40.2	.....	30.25	40.0	37.0
22	.....	.....	35 25	.....	40.0
24	48 0	.....	38.25	48.0	45.0
30	60.0	.....	.....	58 0	60.0
36	72.0	.....	.....	.....	80.0
40	80.4	.....	.....	.....	.....
48	96.0	.....	.....	.....	145.0

The lead should be soft and flow well under the calking-tools. The lead comes in pigs of approximately 100 pounds per pig.

* Dexter Brackett, C. E. Billings: *Some Details of Water-Works Construction*, p. 92.

† *Engineering News*, March 30, 1893, p. 300.

The yarn comes in coils or bales of about 100 pounds each, and is usually cut up on the ground in lengths sufficient to go once around the pipe and lap a little. A quantity of yarn should be kept on hand cut to proper length, so that the yarner will not have to wait to cut it when he is making joints. The following table (Table VII.) gives some data in relation to the amount of yarn required per joint.

TABLE VII.—*Yarn Required—Pounds per Joint.*

Diameter of Pipe.	Southern City.*	M. J. Drummond's Catalogue.
4,	.....	0.19
6,	0.223	0.36
8,	0.34	0.50
10,	0.43	0.60
12,	0.42	0.75
14,	.....	0.84
16,	.....	1.00
18,	.....	1.10
20,	.....	1.20
24,	.....	1.50
30,	.....	1.80
36,	.....	2.16
48,	.....	2.90

The depth to which pipe is laid varies with the size of the pipe and the climate. For moderate sizes, in the Southern States, from 2 feet to 3 feet of covering is usually considered sufficient, while in New England the depth is almost universally 5 feet. In northern New York and in States where the frost penetrates to considerable depths, the pipe is frequently put as deep underground as 6 feet or more.

The cost of trenching and back-filling varies with the price of labor, the nature of the material to be excavated, the depth and width of the trench, and whether wet or dry and the improvement of the surface. For ordinary village work, with unimproved streets, the following table (Table VIII.) gives some figures which may be used as a basis.

* See note, Table VI.

TABLE VIII.—*Cost in Cents of Trenching and Back-Filling Unimproved Streets, Per Foot.*

Diameter of Pipe.	*Hillburn and Suffern, N. Y. 4 Feet.	F. S. PEAKE.					
		Trench and Fill—4-Foot Cover.	Superintendence and Incidentals.	Total Easy Work.	Add. if Wet, with Pumping.	Add. if Hard.	Add. if Stony or Caving Banks.
4	10.1	5.5	2.0	7.5	5.37	10.0	5.0
6	10.1	8.0	3.0	11.0	6.16	12.0	7.0
8	10.1	10.0	3.5	13.5	7.12	15.0	9.0
10	.....	11.5	4.02	15.52	7.8	18.0	11.0
12	.....	12.5	4.5	17.0	8.2	20.0	13.0
14	.....	16.0	5.0	21.0	8.64	22.0	15.0
16	.....	23.0	5.5	28.5	9.14	24.0	17.0
18	.....	26.0	6.5	32.5	9.82	27.0	20.0
20	.....	33.0	7.5	40.5	10.34	30.0	23.0
24	.....	47.0	8.5	55.5	10.7	37.0	25.0
30	.....	58.0	10.0	68.0	11.65	42.0	30.0

The following papers on this subject will also be found of use, as they give the cost in great detail: Barstow: *Cost of Laying Water-Pipe;* Weston, *Cost of Laying Cast-iron Water Pipe*, and an article in *Engineering News*, March 30, 1893, p. 300.

Table IX. will also be found useful in estimating.

TABLE IX.†—*Cubic Yards of Earth in Ditches with Side Slopes of* 1 *Foot in* 10 *per Foot Run.*

BOTTOM WIDTH.	DEPTH IN FEET.											
	4	5	6	7	8	9	10	12	14	16	18	00
2 ft, . .	.36	0.48	0.60	0.72	0 86	0.99	1.15	1.46	1.80	2 19	2.59	2.96
2 ft. 6 in., .	.44	0.57	0.71	0.85	1.01	1.16	1.33	1.68	2.06	2.48	2.92	3.33
3 ft., . .	.51	0.66	0.82	0.98	1.16	1.33	1.51	1.90	2 32	2.80	3.25	3.70
3 ft. 6 in., .	.59	0.76	0.93	1.11	1.30	1.49	1.70	2.12	2.58	3.10	3.58	4.07
4 ft, . .	.66	0.84	1.04	1.24	1.45	1.66	1.88	2.34	2.84	3.40	3.91	4.44
4 ft. 6 in., .	.74	0.94	1.15	1.37	1.60	1.83	2.07	2.57	3.10	3.70	4.24	4.81
5 ft., . .	.81	1.04	1.26	1.50	1.75	2.00	2.25	2.80	3.36	4.00	4.57	5.18

As pipe-laying progresses, notes as to the location of the pipe-line should be made with reference to permanent lines or structures, such as distance out from curb-line or property-line. All specials, valves, etc., should also be carefully located, as well as any unusual features of the work. The notes will be found ex-

* W. C. Foster. Average of about 17,000 feet, most of it hard work, caving banks and full of cobbles. A small part macadamized. Includes foremen, but not engineering About 150 cubic yards solid rock. Labor: foremen, $3.00; laborers $1.35.

† J. Leland Fitzgerald.

ceedingly useful for future reference, and, if properly made and preserved, to save much expense. The writer's practice is to plat them up on maps. A sheet of 8 inches by 14 inches or 18 inches has been found about right. Only one or two blocks are placed upon one sheet, and the sheets are afterwards bound together in book form in such a manner that new sheets can be added from time to time. The whole is properly indexed. Fig. 74 shows such a sheet. By making the first platting on tracing-cloth, blue

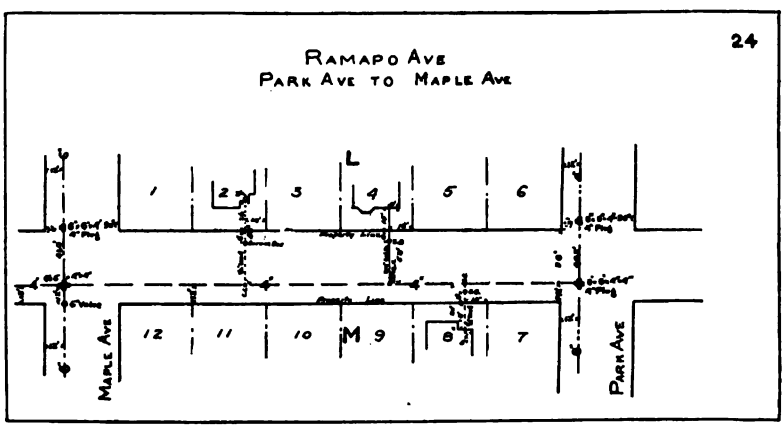


FIG. 74.—Atlas Sheet of Completed Work.

prints can be made for use in the field and a black print on cloth-backed paper for the permanent office record. A scale of an inch to forty feet has been found very convenient. The mains may be represented by various colors or by broken lines, thus:

4-inch pipe, ——— ——— ——— ———
6- " ——— — ——— — ——— — ———
8- " ——— — — ——— — — ——— — — ———
10- " ——— — — — ——— — — — ———
12- " ——— ——— — — ——— ——— — — ———, etc.

The specials and other attachments by signs, thus:

Valves,
Hydrants,
Tees,
Crosses,

giving dimensions, etc., opposite them. It is also well to add some sign showing which ends have bells on them. The kind and diameter of service-pipes is indicated either by colors or broken lines.

Where a single block is too long to go on a single sheet, a double sheet is used. The property lines are shown approximately, as well as the block and lot numbers, according to the assessment or other standard map of the town. The first map in the atlas is a small-scale map, showing the entire lay-out either of the whole town, or of a large division of it where the whole can not be shown. Such a record will be found of untold value in maintenance, and every town will find that it will pay to have a complete record of everything underground either in this or some other equally clear form.

"THE TRUE COLUMN FORMULA" AN IMPOSSIBILITY.

By JAMES L. GREENLEAF.

THE proper formula for the dimensioning of columns is an exhaustless topic, but it has been discussed to the verge of exhausting the interest of the engineer.

He hears predictions vaguely floating about regarding the "true column formula which is yet to be discovered," and looks upon it as a consummation most devoutly to be wished; a something which when it blazes out with the clear brilliancy of an established law, will do for column design what the discovery of the mechanical equivalent of heat accomplished for the science of thermodynamics.

He is conscious that it would be a source of gratification to be able to place column design on such a strictly scientific basis and eliminate empiricism from it, at least to the same extent as has been done for beams. He hopes that the next generation may be able to do this, but, says he, "in the meantime we are obtaining with the present make-shifts practically the same results in actual construction that would be attained if a strictly correct theory of the column was known to us."

He falls back upon the old-time Gordon's formula, or the more

recent straight line formula, or upon any one of a half dozen that are essentially equivalent, and says, "my formula agrees with experiment and is correct for all practical purposes. Don't bother me with any more talk of the column formula."

Such, if I am not mistaken, is the average opinion among engineers whose practice leads them to think at all upon this subject. I do not raise any exception to this opinion, further than to state the belief that, so long as mind is finite in its capacity, we *will never be able to formulate the true theory of the column.*

My reason for this opinion can best be given in the form of an illustration. Imagine a perpendicular and slender rod, mathematically true, and uniform throughout in every particular of cross-section, straightness, bearing of the ends, and physical properties of the material. Under the action of a perpendicular pressure applied along its axis it would yield only by direct crushing, and the strength would be entirely independent of the ratio of length to cross-section. There is the strictly correct theory of the column for the conditions assumed. If a notch, definite in position and size, were to be cut into one side of the rod, it would still be possible to deduce a strictly correct formula for the column under the conditions already stated. This is assuming that the theory of flexure upon which the formula would be based, is accepted as theoretically perfect.

Suppose, however, that some one was to bore a hole here and cut a notch there, crush the fibres in in one spot and partially tear them apart in another, introduce a pebble somewhere under one edge of the bearing of the column and hammer down the edge in another part. Imagine that one is informed in general terms of this maltreatment, but can find out nothing of detail regarding the place, nature, and extent of each separate attack upon the integrity of the rod. One could no more form a strictly correct theory of the column under these conditions than can the politician tell how the vote of Congress in the year 1900 upon the silver question will affect the future interests of his party.

Now, the investigator who undertakes to develop the "true column formula" has to face a mass of unknown and undeterminate conditions that bear a close analogy to, if indeed, they are not identical with the illustration of the rod just given. Even supposing that he is justified in starting with the assumption of strictly homogeneous material, the lack of absolute straightness and uni-

formity in rolled shapes, the secondary strain introduced in building up the column, the maltreatment of the material in the shop, the lack of exactness in fitting the parts, the uncertainties of riveting; all these are conditions that should have definite expression in laws incorporated in the true column formula. It needs no great amount of courage to declare that they will not have expression until that time comes when man no longer sees as through a glass darkly. At present we cover their effect by the dignified expression, the empirical factor, or the more crude safety factor, the former being based upon more or less satisfactory experiments, the latter upon more or less unsatisfactory guessing.

But, it may be urged, cannot the same criticism be applied to the theory of the transverse strength of beams; do not the uncertainties of material and workmanship render any true theory of the beam impossible for us? Undoubtedly, from an ultra-scientific standpoint they do, but all scientific processes, except pure mathematics, are approximations to the truth, and the degree of approximation in the theory of transverse strength of beams is sufficiently close to justify the opinion that we have, essentially, the true theory of the beam, granting that we accept Hook's law as true.

For columns, on the other hand, the opinion is equally justified that we have not, and never can have in this world, the true theory of the column.

The distinction lies right here. The laws of flexure or their equivalent are, and always must be, involved in any true theory of the column as well as of the beam, and if we could eliminate the infinitude of uncertain conditions indicated in the illustration of the rod, the column formula and the beam formula would be equally satisfactory and complete. These uncertain conditions have, however, a vastly different import in the two cases.

With columns the bending moment is emphatically a function of these uncertain conditions, varying as they shift what may be termed the axis of resistance of the column from the straight line occupying the theoretical axis of the column, and very greatly increased by a very slight eccentricity in its position. In one sense a column under stress may be considered in a state of unstable equilibrium, any slight bending at once increasing the bending moment and being in turn increased. For beams, on the contrary, the bending moment is entirely independent of the condition of the beam and can be precisely determined, or, in the case

of restrained beams, is only indirectly and to a minor degree affected by it.

In both cases we virtually equate the resistant moment of a cross-section to the bending moment, to design the cross-section. In the case of the beam we are equating an admittedly uncertain resistant moment to a practically definite bending moment. In the case of the column we are equating an admittedly uncertain resistant moment to an entirely problematical and vastly uncertain bending moment. In the one case one foot at least, is upon solid ground, and we are justified in saying that a practically true theory of the beam is formulated. In the other there is no sure standing ground and all must remain uncertain before us, seen through a fog of infinite combinations that defy human analysis.

This, I take it, is the justification for the statement that a true theory of the column is an impossibility to us, even in the restricted sense in which we have a true theory of the beam.

Having taken this ground I hasten to prevent any possible impression that I array myself against those who are seeking for the "rational" column formula. The word rational means reasonable, and the most reasonable formula is the one which correctly incorporates all known essential laws that pertain to the column. It is the strictly "up-to-date" formula. Therefore, the rational formula does not spring into perfection in a burst of intellectual brilliancy, but is a progressive development as new truths may become established, and the search for it is an extremely sensible occupation.

The rational formula must cover all ratios of length to radius of gyration, serving as well for long columns, for which Euler's formula is strictly rational, as for the short piece that yields by direct crushing. It must therefore involve the laws of flexure as well as direct thrust.

Gordon's formula is based upon these, and in a limited sense, is rational, but a formula must carry us further than Gordon's does into the complicated relation of conditions in the column before it fairly deserves the term. Gordon's formula, $\frac{P}{A} = \frac{C}{1 + q\frac{l^2}{r^2}}$, is too well known to need explanation, but it should not be forgotten that the factor, q, is a little letter that covers a big amount of uncertainty and ignorance.

Experiments are accumulating yearly that are placing the

values of q upon a sounder empirical basis, but these experiments have been carried to the point of rupture of the material, while the laws of flexure, fundamental to the formula, are true only within the elastic limit. Again, the value of q must be varied in some ratio to $\frac{l}{r}$ before Gordon's formula will apply even approximately to very long or very short columns, and be entitled, even in this regard, to be called rational.

Professor Mansfield Merriman has taken a most interesting advance step in these particulars.

In the *Engineering News* of July 19, 1894, may be found a paper in which, with his customary lucidity and clearness of thought, he develops the formula, $\frac{P}{A} = \frac{C}{1 + \frac{n C l^2}{\pi^2 E r^2}}$. The special claim that this formula has to be called rational lies in its not depending upon tests of columns to the point of rupture, and in its adaptability to all length ratios.

It merges into Euler's formula when l equals infinity, and into the expression for direct crushing when l equals zero, thus showing its entirely general mathematical nature. Something in the same direction was accomplished by Mr. Thos. H. Johnson several years ago, from an experimental standpoint, but his formulæ were not placed upon a true theoretical basis. On plotting Mr. Johnson's deductions his straight line formula ran abruptly into Euler's formula, as a tangent into a curve, at a point which agreed with the plotted experiments.

His treatment, although of recognized value as a deduction from experiments, lacked the mathematical flexibility and completeness of Professor Merriman's formula. In this respect the Merriman deductions mark a clear cut advance of the rational formula.

It is my impression that the next step will, of necessity, be built upon Professor Merriman's formula or its equivalent, and possibly it will lie in a modification of the factor, n, that covers the character of end of the column. Further and more refined experiments may disclose a law of variation of n that is as yet unknown.

That which is of far more interest to the practical man, is the effect that further experiments within the elastic limit may have upon the safety factor that must be applied to the formula. It is conceivable that extensive series of experiments upon different

forms of construction, solid, Z bar, channels, etc., may cause a distinction in the safety factor for various forms of columns that will lead to much greater intelligence of design than is now possible. Let it not be forgotten, however, that the safety factor covers the infinity of uncertainties that defy formulation, and it must ever remain our "factor of ignorance." Therefore, while the study of the safety factor may lead to the specializing of the formula for different classes of columns, such study can never rationalize it in the strict sense of the term.

Were this possible the rational formula would become a finality, the completed "true column formula." The designing of columns would then belong among the exact sciences, and the column itself would stand as a monument to the advance of science.

SYSTEM OF "LONG WALL" USED IN NORTHERN ILLINOIS COAL MINES.

By G. S. RICE, E.M.

THE system of mining which is to be described, has been developed by the special conditions of the "third vein" of the northern Illinois coal field. This "third vein" is so called because usually third from the top, but geologically it is No. 2, numbering from the bottom.

In this district the other seams are only occasionally developed, and are worked in but few places. The "third vein" is very permanent and uniform, and is workable through the large district north of the Illinois river, and its annual output is between three and four million tons. The coal is a moderately hard bituminous coal of good quality; in fact, one of the best of the Illinois coals, its actual evaporative power being eight to nine pounds of water per pound of coal under a good boiler. The thickness of the seam is from 2 feet 10 inches to 4 feet, but the greater area only varies from 3 to 3½ feet. While the "third vein" is somewhat rolling locally, the general plane is nearly horizontal, having but a slight raise toward the outcrop at the north.

The coal is underlain with sandy fire-clay, which, at times, is so sandy as to be very hard. The roof is a light drab colored shale

of fine texture, called by the miners "soap stone," from its soapy touch. It is of this character for 10 or 12 feet over the coal. Above that, bands of slate are interspersed with the shale until the upper coal seams are reached about 150 feet above. The total cover above No. 2 vein varies from 100 to 500 feet in thickness in going from the eastern to the western part of the northern district. The surface is rolling prairie. The sand and gravel drift, often several hundred feet thick in the western portion, contains much water, but the shale strata, as a whole, is not fissured or broken by the long wall working, and so the mines are quite dry, even in the case of one mine which passes underneath the Illinois river.

The only exceptions to dryness are in mines at Braceville, which is near the outcrop. There the solid covering is thin, and in a few mines of that neighborhood the roads have to be corduroyed.

In selecting the position of a shaft, in most any part of the "third vein" district, there is usually no natural obstruction to prevent its being placed in the the centre of the given tract. Besides the central hoisting shaft there must be an escape shaft, the present State law says 300 feet away. This distance may be lessened with the permission of the mine inspector. This is usually granted for the long-wall system, as it would be an unnecessary hardship to require such a great distance between the shafts, on account of the large pillar which it would necessitate.

Having selected the position of the shafts, the next point to determine in the planning of the mine is the size of the shaft pillar to be left. Of course this will depend chiefly upon the depth of the shaft, and the nature of the material gone through. The danger is in making the pillar too small, and in a number of cases there have been bad results following this mistake.

Observation of the shaft pillars of mines now open, leads to the conclusion that the strata of this district require, for a safe pillar, that its minimum diameter should be not less than the depth of the shaft. On the other hand, some advocate leaving no pillar at all, expecting that the whole shaft will sink so gradually and evenly that no danger will result; but the writer believes that the risk of racking the shaft is greater than the advantages that might be gained in more quickly opening the long-wall face. The usual plan of the district is to make the shaft pillar diamond-shaped, the "main bottoms" (termini of the main entries) occupying the long diameter. The escape is placed near the line of

the short diameter; and it has been usual in the past to make it about 100 feet away from the main shaft.

After the shafts have been sunk, and connection has been made by driving headings from one to the other to establish a current of air, the "main bottoms" are pushed forward. If the diamond lies north and south, these will be the termini of the "main north" and "main south" entries. For a mine which is to have a large output, the "bottoms" are double-tracked for 250 feet on each side of the shaft, and, if practicable, are made with a down grade toward the shaft. These grades cannot always be established at once; the mine must be developed sufficiently to find how the seam is running. It may be necessary in some cases to lower the shaft if it is found that it has been sunk on the hill of a seam. At the end of the switch of the double track, the entry is narrowed to single track width, and just beyond two entries are turned off, one 45 degrees to the left, the other 45 degrees to the right, with an interval of about 40 feet between them. These form what are called "main 45 degree" entries, and run on the diagonals, so to speak, of the tract.

After the latter four entries have advanced about 30 feet, from each an entry is turned off at 45 degrees to run due east or due west respectively, and these complete the main permanent entries, making ten in all. From the east and the west entries, entries are turned and directed towards each other to block out the shaft pillar. Single entries are usually used in blocking out the pillar, but there is much difficulty in airing, even when boxes are used, to carry the air to the face, and if the pillar is large, it becomes very severe on the miners.

A better way with large pillars is to have double entries with "cross-cuts" between, spaced at the right intervals for room-roads, then, connections having been made all around the shaft pillar, all is ready to begin the long wall face at once from the side of the outer block entry.

When the blocking-out entries are single, the rooms are started narrow for a certain distance, then are broadened till they meet and form a continuous face around the block. Still another plan is to use a broad entry, packing on each side of the roadway, and starting rooms off it at once. This plan was used at the Ladd mine (see Fig. 1), where the width of the entry or room was 33 feet. The method was successful, except for a difficulty in airing, in spite of the air-boxes.

The spacing adopted for the branch roads in this district is 42½ feet from centre to centre of road, measured at right angles. This makes an even 60 feet, when measured along the 45-degree entries, from which all the room-roads are afterward turned. Although not properly "rooms," the branch roads are so called locally, and we use this term in describing them.

Two miners work in each room in "getting" coal. They first prop or "sprag" the coal-face, then undercut the coal in the fire-clay to a depth of from 16 to 20 inches; to do which the miner must lie on his side. The sprags are then knocked out, letting down as long a strip of coal as was undercut. At the beginning of the "long-wall," before the roof weights down the coal, the undercutting is hard, and, indeed, where the fire-clay is very sandy, the cutting may have to be done in the lower part of the seam itself, and the coal require to be wedged down.

The room-track is laid up to within five or six feet of the face, and the car is brought in as close as the brushing will allow. The track is in the middle of the ground (42½ feet wide, as already mentioned) apportioned to each pair of miners. The coal has to be carried or rolled along the face to load it into the car. After the coal has been loaded out, walls are built up to the roof on either side of the roadway, and to within a couple of feet of the face. The walls are built with the rock taken down in the roadways to give height. This is called brushing. The method of doing it is, to carry the face of the brushing full thickness and up to a bedding plane, cutting with picks at the sides and pulling down the slabs.

Before the mine is well started, there may not be enough rock to build the walls and fill the "gobs;" in that case, soft-timber "cogs," which are sticks of timber laid log-cabin style, must be built. After the mine is well opened there is, usually, too much rock; and in some mines it averages one car of rock to every four or five of coal that must be taken out of the mine. Behind the walls, or "buildings," which must be six feet thick, are the "gobs," as they are called, which are filled as nearly as can be with the clay cuttings. If none, or not enough rock is at hand, timber cogs must be put in, for, in this system of long wall it is very essential that the roof be supported evenly all over; if it is not, the weight is taken from the face, and also the sides of the entries are liable to be pushed in. Where other supports than

clay or rock are used, they must not be too rigid. This is the object of the soft-wood cogs, which yield in much the same proportion as the walls and gob-filling.

After the main entries have progressed about 210 to 270 feet, depending upon local position, "cross-entries" are turned at 45 degrees. These cut off the room-roads, but new ones, off the last entry, are started at the same intervals, that is, 60 feet measured along the entry. The distance between the "cross entries," or, in other words, the length of the room-roads, is determined by the rapidity with which the roof settles. This varies somewhat in different parts of the district, as it is necessarily proportional to the overhead weight; but the room is made as long as possible, just so that it does not require additional brushing to make headroom for the mule and loaded car before being cut off and abandoned.

The roof settles most in the first few months, but it is several years before it is entirely settled, by which time the gob has been squeezed down to one-half or one third its original thickness.

The cross-entries themselves are cut off by the cross-entries started further in, thus making large diamond-shaped areas of "gobs," untraversed by open roadways; for as soon as a roadway is abandoned, it in a few months' time, falls from the roof and the squeezing in of the sides fill it up.

If the mining conditions are at all equal throughout the mine, the form taken by the long-wall face is that of a rough circle, and on this account the system is sometimes called "the circular long-wall."

This "third vein" is quite free from strongly-marked slips or faces; and as it makes no difference in its mining what direction the work may progress, provided the face has no sudden bends, which would take off the necessary roof weight, the circular form is of no disadvantage. The roof is also very free from slips, and vertical cracks or joints, until the coal has been mined below it; but when the coal is brought down in a long strip, it marks the roof just where the break of coal has occurred, and along these marks the roof afterwards breaks. These "breaks" seem to run up indefinitely, and oftentimes they can be followed up to the "black slate," 8 or 10 feet above. This peculiarity has had a marked influence in adopting the system of mining. When the "breaks do happen to run parallel with the course of an entry,

there is endless trouble from the slabs dropping out. The roof is apt to cut away over the side walls, and then, the only thing that can be done is to fill the top with timber. This, of course, is expensive, and were it the condition prevailing throughout the whole mine, would prevent the commercial success of the mine.

On the other hand, if the breaks run across the entry, pieces may splinter off, and there may be a festooning down of these pieces where there is no timber; but they interlock overhead, and there is nothing like the difficulty in keeping the entry in condition. From this, it is evident that it is necessary to have the roadways head on to the coal-face as nearly square as possible. The 45-degree system more nearly allows this than any other arrangement of roadways; and indeed, all of the other systems, both long-wall, and room and pillar, that have been tried in this seam have been unsuccessful.

The mode of ventilation is very simple. Usually, the hoisting shaft is made the upcast, and one compartment of the escape-shaft is made the downcast. The air is split at the bottom of the downcast into two currents, running east and west, respectively, in the example selected. When they reach the face they split again moving north and south. The currents travel around the face of the workings, each having a quarter-circle to go. They come together again at the heads of the north and south entries, respectively, and passing to the hoisting-shaft escape upwards. It requires but a few doors, which are placed near the main bottom, to make these currents, and as the splits are of nearly equal length; no regulators are needed. The ventilation is very effective, as fresh air is brought to just where needed, that is, along the face where nearly all the men of the mines are at work. Entries other than those mentioned get sufficient air from leakages and opening of the doors to let the cars through.

One objection that this long-wall system has, in common with all long-wall systems with continuous faces, is, that in "opening up," it often takes a year or two to reach the full capacity of the hoisting and loading plant, and when that has been reached, the face keeps on getting larger and larger until at last some sections of the mine have to be closed. However, where the shaft is shallow, instead of temporarily closing a portion, it is usual to distribute the men more, having but one in each room; and, when a certain limited area has been worked, say 160 acres, it is considered

cheaper to sink a new shaft and move the plant rather than to keep open a large number of entries, with the expectation of having to reopen those parts of the face which had temporarily to be shut down.

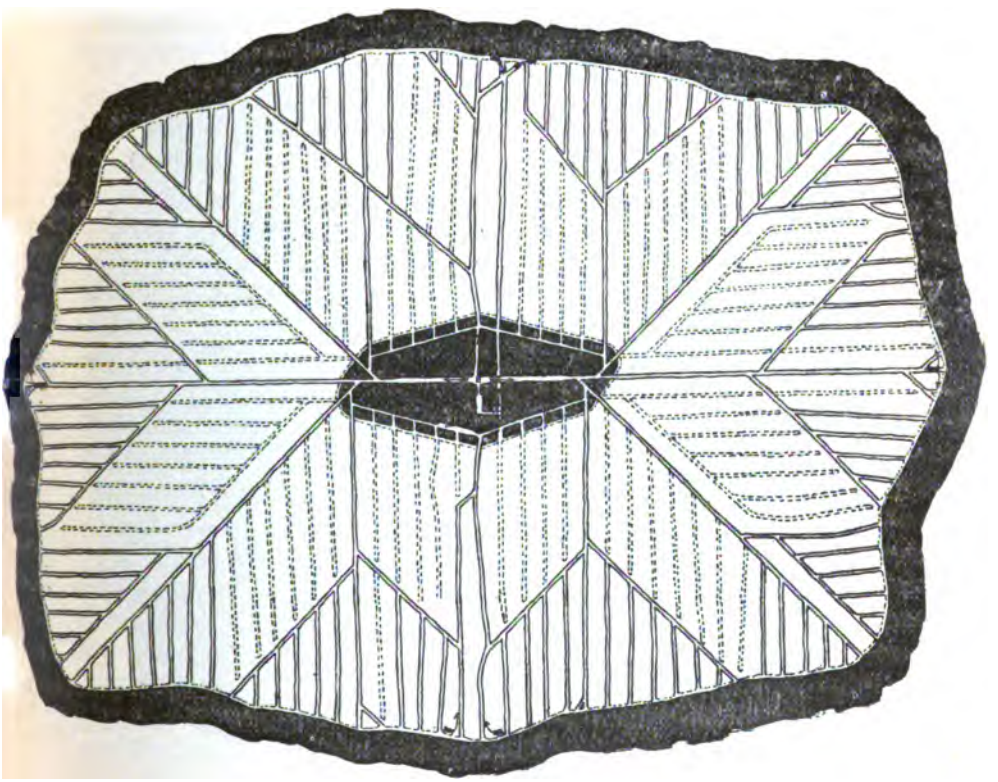
Hitherto most of the mining has been done in the eastern part of the field where the mines are all shallow, most of them under 100 feet in depth. But now, mining has begun in the north-western part where the seam is deeper and overlaid with wet drift. There, since shafts are expensive to sink, they must be made to work out large territories, which can be accomplished with mechanical haulage. At present, haulage is done entirely by mules, in all the "third vein" mines and perhaps more cheaply than could be done by mechanical means, as the roadways are many and distances short.

Payment to miners is made according to the tonnage of lump coal they mine and load out, which is about 80 per cent. of the gross weight of the coal. The price in the eastern part of the field is 87½ cents in summer and 90 in winter. In the western part it is 5 cents less for both seasons. This is a differential allowed the operators to offset the extra railroad haul to Chicago, which is the largest market for this field. The miner, for the price paid him for lump coal, loads out the fine coal, and must also carry 18 inches of brushing in the roadway, build the pack-walls, fill the gobs and load out the surplus rock. His items of expense, are shovels, picks, a small monthly smithing charge, and oil for his lamp. With steady work for both miner and mine, which is essential to the fullest success of the long-wall system, a good miner can get out four or five tons of lump per day. The average of good and bad would be three tons per man, which makes good wages.

The present difficulty, however, is over-production of coal. Too many mines have been opened for the market and as a consequence, the mines for several years have averaged little over half time, and the earnings of men and mines have been small. One trouble that not working each day entails, is, that the careless miner does not load out all his fine coal, for on the days the mine does work he wishes to load out only lump coal as that is all he is paid for. The fine coal if left in the gobs in any considerable quantity, may be ignited by the sulphur in the form of iron pyrites, which here and there is found in small streaks in the coal, and has not been sent out, as it should be, with the rock. A fire in the

"gob" is an awkward thing at the best. It must be reached promptly by cutting a passage right to the heart of the fire, and loading out the burning stuff. If the fire should be neglected, it would soon be beyond control, would get into the roof, which contains enough bituminous matter and specks of the sulphur to fire, and the whole district would have to be abandoned. Double fire-walls of brick

FIG. 1.



with sand between would then have to be erected in all the roadways round about.

In one of the mines of the field, such a fire has been smoldering for years through a considerable district of the mine.

Fig. 1 shows a typical mine of the district. The full lines show the working roads, the dotted lines the roads that have been cut off and therefore abandoned. In this particular mine the conditions were highly favorable, and it was noted for the exceptional

rapidity of development, and working out of the coal in the tract assigned to it. The narrow-work around the shaft was completed in two months. The long-wall face was started with thirty rooms. During the first month the largest output in a day's run was 300 tons, but nine months later it had reached 1038 tons. The highest record for a day's run of ten hours during the whole life of the

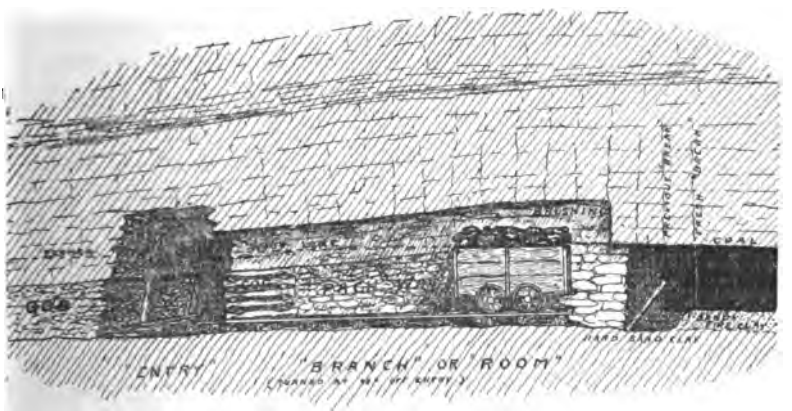
FIG. 2.

mine was 1900 tons gross weight, or 1702 tons of lump. In one month with twenty-four working days there was hoisted and loaded 25,057 tons of lump coal. The life of the mine was comprised in 766 working days, during which about 175 acres of the coal seam were mined out, giving 688,619 tons of lump coal.

Fig. 2 shows a map of Ladd mine eight months after the narrow entries had reached the boundary of the pillar, and the several isolated long-wall faces had just started. At the end of four months

a continuous long-wall face had been formed around the block. In the drawing, the lines shown circling around the pillar more or less parallel, are the faces of the long-wall on the first of each month. Those parts of the mine in which the fire-clay under the coal was soft enough to permit mining in it are readily observable, as the places where the face is farthest advanced. This mine is a double one, that is, it has two hoisting shafts. The roads are planned to serve either shaft, so when the output exceeds the capacity of one shaft the other can also be used. The average capacity of both shafts together should be not far from 3000 tons

FIG. 3.



of coal, gross weight. The pit-cars at this mine hold about one ton, gross weight. This is a somewhat larger capacity by 400 or 500 pounds than the pit-cars have in the eastern part of the field. The engines hoist a car through the 500 feet to the top landing in ten seconds. Four cars per minute can be hoisted by the engine at either shaft. The ventilating is done by 24-foot forcing fan with straight paddles and spiral-expanding casing.

Fig. 3 shows a profile sketch of the head of a roadway in the mine, illustrating the method of propping and undercutting the coal face, and the settlement of the roof further back.

The settling of the roof is appreciable at the surface even when the seam is at a depth of 400 or 500 feet; but so gradual is it, and without vibration, that the deep mines have caused no trouble in going under railroad tracks, and even under brick buildings, as has been done at La Salle.

THE CONDENSATION OF FUMES BY STATIC ELECTRICITY.

By MALVERN W. ILES, SUPERINTENDENT OF THE GLOBE SMELTER, DENVER, COLORADO.

I DESIRE to place on record certain interesting facts, and also a portion of the literature relative to the use of static electricity for the condensation of fog, mist, smoke and fume.

In the *Scientific American Supplement* for June 28, 1884, No. 443, there occurs an article entitled "Dust-free Spaces," which is presumably a fairly correct report of a lecture to the Royal Dublin Society, by Dr. Oliver J. Lodge, April 2, 1884.

In this article we learn that Dr. Lodge carried on some very remarkably interesting experiments on the subject of dust, in conjunction with Mr. J. W. Clark, Demonstrator of Physics in University College, Liverpool. New ideas, new facts are here presented which, in the opinion of the writer, should be carefully studied both by students in metallurgy and electricity.

Dr. Lodge uses the following words: "But we (Lodge and Clark) have found another and apparently much more effectual mode of clearing air than this." (Reference being to dust particles collecting upon cold surfaces.)

"We do it by discharging electricity into it. It is easily possible to electrify air by means of a point or flame, and an electrified body has this curious property, that the dust near it at once aggregates together into larger particles. It is not difficult to understand why this happens; each of the particles becomes polarized by induction, and they then cling together end to end, just like iron filings near a magnet. A feeble charge is often sufficient to start this coagulatory action. And when the particles have grown to big ones, they easily and quickly fall."

Professor Lodge shows that a fog can readily be turned into a rain; also that jars containing tobacco smoke, or various smokes or fumes, can be quickly and readily transformed into particles of appreciably large size or flocules, and that in this state they settle readily.

Another article appeared in the *Scientific American*, June 27, 1885, upon this subject, entitled: "A New Application of Electricity." In this article we learn that Mr. Alfred O. Walker, one of the partners of the firm of Walker, Parker & Co., at Bagilt, in

North Wales, has, in conjunction with Mr. W. M. Hutchins, the manager of the works, applied practically the discoveries of Lodge and Clark, in the condensation of lead fume by static electricity.

The writer thinks that directors of mints and superintendents of plants handling any volatile metal, would obtain valuable suggestions from the last named article.

B. Rosing, of Tarnowitz, claims to show in July 10th copy of the *Berg- und Huttenmannische Zeitung*, that this fact was known in 1850 to Guitard, who showed that tobacco smoke in a glass readily condenses by introducing into the glass one of the wires from an electrical machine.

Rosing also cites Wiedemann's work on electricity, *Lehre von der Electricitat*, as referring to this in Vol. I., p. 33.

Through the kindness of the late Francis C. Blake, Superintendent of the Pennsylvania Lead Works at Mansfield, Pa., the writer came into possession of a copy of a patent granted in this country to Alfred O. Walker, on May 25, 1886, No. 342,548, entitled, "Process of Depositing Solid Particles Suspended in Air or Gas."

In a French paper, entitled, "E. Dieudonné," in *La Lumiere Electrique*, there occurs an article entitled, "The Condensation of Fumes by Static Electricity." This article was translated by the *Scientific American*, Supplement No. 535, April 3, 1886. There are two drawings in this article which should be highly interesting to all interested in metallurgic fume; likewise, those interested in the smoke question in any of its multitudinous phases.

We understand, at the Bagilt lead works there was used a modification of the Wimshurst electrical machine. The success of this machine is not known to the writer; neither is the success of the experiments at any place in Europe known to the writer; still, he thinks the subject of the utmost moment, in view of the recent discoveries of Tesla, who, we learn, has transformed current electricity into static electricity.

The writer believes the subject of the volatility of gold, silver, and lead, has not received proper and sufficient attention; and many substances, like copper which is classed by the practical metallurgist as being non-volatile, are, indeed, found to suffer at least 6 per cent. loss in fume. This fact I glean from a little pamphlet written by the highest known authority—fifty copies only have ever been published.

With a hope of getting some electricians of prominence interested

in this subject in conjunction with the writer, he stated briefly the facts herein-above mentioned to the class at Denver, Colorado, now studying electricity under the organization of the National School of Electricity, at the meeting held May 28, 1895.

If there can be discovered some cheap mode for the generation of static electricity, we predict that it will enable the metallurgist to save a very large amount annually in all the well-known volatile metals.

ON THE STUDY OF SLAGS FROM LEAD FURNACES WITH THE OBJECT OF PRODUCING LIQUATION OR CRUST EFFECTS.

By JOSEPH STRUTHERS, PH.D.

WHILE pursuing an investigation upon the physical properties of slags, the following results were obtained which are of sufficient interest and value to record. This branch of the investigation embraced the study of slags from lead furnaces for the purpose of ascertaining the cause of crusting or liquation. Without going into a discussion of slags as to types, formation, composition, properties, etc., references thereto being found in the appended bibliography, I will state simply the results. In order to obtain a sufficiently high temperature, two gas furnaces were experimented with. One was of the regenerative type, with natural draft, and the other was direct gas-fired with strong blast.

The regenerative furnace* presented too many objections both as to construction and manipulation, and could not be successfully employed. The direct firing furnace with blast was made by the American Gas Furnace Company, and was of their standard crucible type. This furnace operates by blast, and its ease of manipulation rendered it exceedingly useful for the purpose employed. It gave good results both as regards temperature and manipulation, its only drawback being the lack of regeneration. Could there have been some system of preheating blast and gas, or blast alone, high temperatures could have been obtained in much less time.

To get a very high temperature required a long time of fast running, so that the brick work of the enclosure would be heated

* A French Regenerative Gas Furnace. By Joseph Struthers. SCHOOL OF MINES QUARTERLY, Vol. XV., No. 2.

to a white heat; when this was done, a temperature of 1500° C. to 1550° C. was easily obtained.

Numerous attempts were made to cause liquation or crusting of slags when in a molten condition; at least thirty trials were made to produce this result, in only two of which did the crusting manifest itself. The first successful attempt with crust formation was later on destroyed in studying the effect of higher temperature on this crust. It became molten, and refused to crust again except when temperature was so much lowered that the crust formed was from cooling. Repeated meltings and coolings failed to reproduce any crust at a high temperature.

The second successful attempt gave a mass of material in the crucible which had a distinctly different fracture of crust and body when cold. The body of the slag was amorphous and strongly vitreous. The crust showed evidences of crystalline structure, but no distinct crystals, and lacked the brilliant vitreous lustre of the main body of slag. In both of these cases metallic iron was reduced from the slag, forming a button at the bottom of the crucible, and changing the oxygen ratio of the slag.

The facts deduced from the evidence goes to show that this crust formation is due to the expulsion of exactly the proper amount of volatiles (lead and zinc) from the surface, and the reduction of oxide of iron to metallic iron in proper amount to change the strongly basic slag into one of more acid character. The effect of these changes is to produce a relatively more infusible mixture at the surface, which at that temperature solidifies, while the molten mass below remains liquid throughout.

This suggestion is further indicated, as when once all is molten there is a further elimination of volatiles and reduction of iron in amount to exceed the exact quantity necessary for the formation of this more infusible crust, and further attempts to produce a a second crusting from the molten mass in the crucible was never successful.

At least thirty attempts were made, using different slags alone and in admixture with each other, but to no purpose as far as crust formation was concerned. The results of some of these tests are quoted later.

The handling of the slags under heat is exceeding difficult, their lead and silver contents preventing the use of platinum crucibles; their high iron contents preventing the use of the clay

crucible, which is cut through very shortly after the slag is molten; their study as to effects of high heats preventing the use of iron crucibles, which would deteriorate; and their study as to long continued high heats preventing the use of the graphite crucible, as the carbon reduces the FeO in the slag to metallic iron; thus changing the type of slag.

Attempts were made to basic-line these graphite crucibles; but not having pressure apparatus, they were not successful. The crucibles which gave the best results were of graphite; but, as mentioned above, they had the objections of changing the character of the slag by the reduction of the oxide of iron by the graphite, and a further change in the character of the slag by the assimilation of the silica of the sand and clay, which were exposed to the cutting action of the slag by the removal of the graphite.

The cutting of the crucibles was generally at the level of the top surface of the molten contents. In one or two cases only did the material cut through below this level.

Some results obtained in the fusions:

TRIAL NO. 1.

350 grammes of slag from the Arkansas Valley smelter. Sp. gr., 3.52; crystalline structure; dark gray in color.

10.45 A.M.—Furnace started.

11.05.—Crucible placed in furnace.

11.15.—Red heat. Slag softening.

11.25.—Bright-red heat. Completely molten. ZnO fumes.

11.35.—Quiet boiling. Higher heat until

1.10 P.M.—Crust forming on surface.

2.—Blast off.

2.15.—Gentle blast on, to have gradual cooling.

4.—Blast off.

Cooled in furnace until the following morning.

Results.—The crucible was corroded one-third through at the level of the molten contents, while in the bottom of the crucible there was formed a button of white iron, 47 grammes in weight, reduced from the slag.

The fracture of the crusted slag showed a vitreous, shiny lustre in the body of the material, of no crystalline tendency whatever. The crust lacked the strong lustre of the body part and evinced crystalline tendencies.

The change in fracture from the earthy appearance of the original fractured surface to the vitreous appearance of the resultant fractured surface was due to the reduction of the 47 grammes of iron, which changed the composition of the slag from a strongly basic to an acid character.

TRIAL NO. 2.

Character of slag same as before. Sp. gr., 3.43.

Amount taken, 500 grammes.

11 A.M.—Furnace started and crucible in.

11.30.—Bright-red heat. Strong fumes from volatilized PbO and ZnO.

12.15.—Molten.

12.45.—Higher temperature.

1 to 4 P.M.—Alternate raising and lowering in endeavoring to form crust, but without success.

4.—Cooled in furnace.

Results.—A 54-gramme white iron button. The slag was strongly vitreous, except at the core, which had an earthy lustre. The color was brown. There was no crystalline indication whatever. The crucible lining showed strong corrosion. No crust was formed, as, probably, there was not a proper amount of change to produce the result sought—too much or too little PbO or ZnO expelled or not proper amount of FeO reduced.

TRIAL NO. 3.

Same slag. Sp. gr., 3.46.

Amount taken, 600 grammes.

10.30 A.M.—Furnace started.

10.45.—Crucible charged. Red heat.

11.10.—Molten and fuming from volatilized ZnO and PbO.

11.20.—Red heat.

11.30.—Bright red heat.

11.40.—Lower to red.

11.50.—Ditto.

12.—Furnace stopped.

Result.—But little change in appearance of fracture or surface.

A small button—13 grammes—of reduced white iron was produced.

TRIAL NO. 4.

Same slag. Sp. gr., 3.45.

Amount taken, 500 grammes.

11.15 A.M.—Furnace started.

11.30.—Materials charged.

11.45.—Temperature raised to

12.—Dark red.

12.15 P.M.—Red heat. Fuming strongly.

12.30.—Melting.

12.45.—Melted.

Temperature maintained at good red until

3.—Gas and blast off. Cooled in furnace until the following day.

Results.—A 55-gramme button of white iron. A vitreous appearance of slag fracture, which was amorphous except at the sides of the blow-hole cavities, where crystals of hexagonal shape attempted to form.

The color of the slag result was dark brown.

TRIAL NO. 5 AND OTHERS.

Summary of results not recorded, as the main object of these trials was to produce the crusting.

The effect on the slag combinations was varied, depending on the height of temperature and length of time in furnace. Incidentally, attempts were made to reduce larger amounts of iron from the slags, but as this required more carbon, and the carbon was taken from the crucible at the level of the molten slag, corrosion and cutting through always occurred.

The following bibliography was compiled by me, and while I do not claim that it is complete, it contains references to all the prominent articles in scientific literature from 1880 to 1895, with a few of the more important references previous to 1880.

Nearly all the abbreviations employed are sufficiently clear to prevent misunderstanding; the exceptions are included in the following list:

I. and S. I.—Proceedings of the Iron and Steel Institute.

Eng. News.—Engineering News.

T. A. I. M. E.—Transactions of the American Institute of Mining Engineers.

E. and M. J.—Engineering and Mining Journal.

S. of M. Quar.—School of Mines Quarterly.

I.—Slag Formation.

Date.	Publication.	Vol.	Page.	Title of Article.	Author.
1884	Principles of the Manufacture of Iron and Steel,		118	Heat units required for fusion,	Bell, I. Lowthian.
1886	I. and S. I.,		310	Heat required for fusion of blast-furnace slags,	Akerman, R.
1886	E. and M. J.,	41	227	Formation of siliceous slags,	Elbers, A. D.
	"	42	75, 273	"	"
	*Berg. u. H. Zeit.,	47	253	"	"
	*I. and S. I.,	1888 2	241	"	"
	E. and M. J.,	42	128	Notes on formation of siliceous slag,	Henrich, C.
1887	"	45	165	Formation of igneous silicates,	Elbers, A. D.
1889	Stahl u. Eisen,	9	756	Blast-furnace slags,	Gredt, P.
	*I. and S. I.,	1889 2	412	"	"
	Jernkontorets Annalen,	5 & 6		On the temperature of formation of blast-furnace slags,	Akerman, R.
	*Stahl u. Eisen,	10	424	"	"
	Jernkonterets Annalin,		5, 6	Heat of formation of blast-furnace slag,	"
	*I. and S. I.,	1890 2	760	"	"
1890	E. and M. J.,	49	637, 675	Pyrometry and pyrometric data,	Howe, H. M.
1894	"	57	297	Smelting reactions of blast-furnace slag,	Elbers, A. D.

NOTE.—The * signifies that the article is a reprint or abstract.

I.—Slag Calculation.

Date.	Publication.	Vol.	Page.	Title or Subject.	Author.
1872	T. A. I. M. E.,	1	154	Blast-furnace slags,	Robertson, Kenneth.
1876	"	5	563	Notes on a metallurgical campaign,	Jernegan, J. L., Jr.
1882	Compendium der Metallurgischen Cheme. Bonn.,		98	Tables of proportions of silica and bases required to form singulo-, bi- and sesquisilicate slags,	Balling, C.A.M.
	*The Metallurgy of Lead. By H. O. Hofman,	1892	134	"	"
1887	E. and M. J.,	44	10	Calculation of slag components,	Murray, Geo.

I.—Slag Calculation, continued.

Date.	Publication.	Vol.	Page.	Title or Subject.	Author.
1887	*I. and S. I.,	2	292	Calculation of slag components,	Murray, Geo.
1892	T. A. I. M. E.,	21	364	Calculation of slags,	Langdon, N.M.
	*S. of M. Quar.,	14	74	"	"
	*I. and S. I.,	1892 2	438	"	"
	E. and M. J.,	53	281	Calculation of slag components,	Murray, Geo.
	T. A. I. M. E.,	21	848	Titaniferous ores in the blast-furnace,	Rossi, A. J.
	*Iron Age,	48	970		
		49	342	"	"
	*I. and S. I.,	1	409	"	"
1893	State School of Mines, Quarterly. Col.,			Slag calculation,	St. Dizier, J. L.
	*S. of M. Quar.,	15	68	"	"

Note.—The * signifies that the article is a reprint or abstract.

I.—Composition.

Date.	Publication.	Vol.	Page.	Title or Subject.	Author.
1864	Metallurgy of Iron and Steel,	1	39, 497	Composition, Mn and S,	Percy, John.
	"	1	501, 503, 505, 614 509,512,49	"	"
1868	Metallurgy of Lead,	1	87, 124, 142, 153	Analyses and composition,	Crookes and Röhrig
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1870	"	3	54,604,147	"	"
1872	T. A. I. M. E.,	1	97	Smelting of argentiferous lead-ores in Nevada, Utah and Montana,	Hahn, Eilers, Raymond.
	"	1	145	Blast-furnace slags,	Robertson, K.
1873	"	2	19	Economical results of smelting in Utah,	Dagget.
	"	2	96	Wyandotte Silver Smelting and Refin. Works,	Courtis, W. M.
	"	2	81	Mode of subdividing and special use of blast-furnace slag,	Bodmer, J. J.
	"	2	75	Manufacture of Bessemer pig-metal,	Witherbee, T.F.
1874	Elements of Metallurgy,		192, 194	Blast-furnace slags,	Phillips, W. B.
	T. A. I. M E.,	3	51. 265, 326, 334	Analyses,	Witherbee, T.F.

I.—COMPOSITION, continued.

Date.	Publication.	Vol.	Page.	Title or Subject.	Author.
1875	T. A. I. M. E.,	4	375	Cedar Point Iron Co.'s furnace,	Witherbee, T. F.
	"	4	52	The Swansea silver-melting and refining furnace,	Jernegan, J. L., Jr.
1876	"	5	319, 327	Some points on the treatment of lead-ores,	Williams, C. P.
	"	5	572	Notes, etc.,	Jernegan, J. L.
	"	5	613	Manufacture of ferro-manganese in the blast-furnace,	Ward, W. P.
1877	"	6	111, 117	Strength of wrought-iron,	Holley, A. L.
1879	"	8	158	Washing phosphoric pig-iron,	"
	"	8	322	Notes on Siemen's direct process,	"
	"	8	350, 351	Blast-furnace working,	Kennedy, Julian.
	"	8	539, 526	American bloomary process,	Egleston, T.
	"	8	71	Use of determining slag densities in smelting,	MacFarlane, T.
	E. and M. J.,	28	281	Blast-furnace slags,	Wood.
	B. u. H. Zeit.,		38	Smelting sulphurous nickel ores,	Schweder, G. P.
1880	E. and M. J.,	30	156, 171	Chemical and Metallurgical considerations in the treatment of Leadville ores,	Iles, M. W.
	T. A. I. M. E.,	9	54-55	A short blast at the Warwick furnace,	Birkinbine, John.
	"	9	261, 266	Chemical reactions in Bessemer process,	King, Chas. F.
	"	9	681 to 727	Copper refining in the United States,	Egleston, T.
	"	9	17-21	Self-fluxing properties of Chateaugay magnetite,	Kemball, J. P.
	"	9	74, 80, 83	Discussion of Jas. P. Kemball's article.	
	Bied. Centr. 18,		770	Slag obtained in dephosphorizing iron,	Pochin, W.
	*I and S. I.,	1881	341	"	"
1881	Zeit für B. u. H. vereins für Steiermark u. Kärnten,	13	53	Experiments on iron slags,	Ledeber, A.
	* I. and S. I,	1881	671	"	"
	Bul. No. 26, U. S. Geol. Surv.,		50-72	Classification of slags,	Howe, H. M.
	"		93, 94, 98	Composition of slags,	"

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I.—Composition, continued.

Date.	Publication.	Vol.	Page.	Title or Subject.	Author.
1881	T. A. I. M. E.,	10	38 to 47	Investigations on the ore-knob process,	Egleston, T.
	S. of M. Quar.,	2	145	Slag analysis,	Iles, M. W.
	*E. and M. J.,	31	58	"	"
1882	Mineral Resources of United States,		325	Slag composition,	Hahn, H. O.
	*E. and M. J.,	36	114	Lead in the West,	"
	Compendium der Metallurgischen Chemie,		134	Slag composition,	Balling, C. A. M.
	T. A. I. M. E,	11	56	High percentage of lime in shaft-furnace slag,	Schneider, A.F.
	*E. and M. J.,	34	283	"	"
	T. A. I. M. E.,	11	161	The practical metallurgy of titaniferous ores,	Bowron, Wm. M.
	I. and S. I.,		289, 354	Analysis,	
	Zeits des Ver. Deutscher Eisenhüttenleute,			Phosphorescent blast-furnace slag,	Frank, G. A.
	*E. and M. J.,	33	274	"	"
1883	S. of M. Quar.,	5	351	Decomposition and analysis of slags,	Iles, M. W.
	*Chem. News,	50	194	"	"
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1885	Studies over "Slagger,"			The mineralogical constitution of slags,	Vogt, J. H. L.
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1886	E. and M. J.,	42	40, 75, 128, 273	Slags,	Elbers, A. D.
	T. A. I. M. E.,	15	59, 64, 72	Copper-ores of the southwest,	Wendt, A. F.
	"	15	612	Concentrating and smelting at Tombstone, Arizona,	Church, John A.
	E. and M. J.,	42	40	Rôle of alumina in slags,	Heinrich, Carl.
	B. u. H. Zeit.,		547	Lead, silver and copper processes in the Altai mountains,	Kurnakoff.
	Jernkontorets Annalen,	12	127	The violet color of titaniferous slags,	Tamm, Dr.

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Date.	Publication.	Vol.	Page.	Title or Subject.	Author.
1886	*I. and S. I.,		915	The violet color of titaniferous slags,	Tamm, Dr.
	I. and S. I.,	2	88	On a rare blast-furnace slag,	Bauermann, H.
	E. and M. J.,	41	336	Lead-furnaces, slags and fume condensation,	Hutchings, W. M.
	U. S. Geol. Survey, Monograph No. 12,		660	Geology and mining industries of Leadville,	Emmons, S. F.
	B. u. H. Jahrb der k. k. Bergak.,	34	59	Slag analysis,	Prziwoznik, E.
	*I. and S. I.,		318	"	"
1887	T. A. I. M. E.,	16	260	Slag from matting dry auriferous silver-ores,	Austin, W. L.
	"	16	148	Slag analysis,	Brainerd, A. F.
	"	16	344	"	Garrison, F. L.
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	Revue Univ. des Mines,	20	459	Basic Bessemer slag,	Harbord, M. F. W.
	*I and S. I.,	1	425	"	"
	Modern Copper-Smelting,	1887	Index	Composition of slags,	Peters, E. D., Jr.
	I. and S. I,	1	404	Composition of crystalline slags,	Rammelsburg, C.
1888	T. A. I. M. E.,	17	606	Iron saved from Bessemer converter slag,	Cook, Robt. A.
	"	17	140	Slag in Birmingham district,	Gordon, F. A.
	"	17	470	Analysis of Muirkirk furnace slag,	Dewey, F. P.
	B. u. H. Jahrsb. d. k. k. Bergakademie,	36	89–93	Slag analysis,	Prziwoznik, E.
	*I. and S. I.,	1	315	"	"
	Bul. Soc. Française de Minerale,	9	287	Crystallized slag,	Foqué, F.
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	"	18	677–679	Treatment of Scotch hearth-slags,	Dewey, F. P.
	"	18	724	Thermal properties of slag,	Howe, H. M.
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	E. and M. J.,	50	744	Aluminate slags,	Henrich, C.
	Stahl und Eisen,	10	365	Converter slag.	vom Rath, G.
	*I. and S. I.,	1890 2	793	"	"

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	*I. and S. I.,	1891 1	368	"	"
1891	L'Industrie Revista Technica et Economica,	5	153	Analysis of blast-furnace slag,	Namais, R.
	*I. and S. I.,	1	445	"	"
	Iron Age,	47	1015	Pottstown Steel Works,	
	*I. and S. I.,	2	280	"	
	Iron,	37	523	Recovery of metallic iron from slag,	May, W. J.
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	Stahl u. Eisen,	11	1–8	Composition of blast-furnace slags,	Platz, B.
	*I. and S. I.,	1892 1	406	"	"
1892	T. A. I. M. E.,	21	72	Desilverization of lead slags,	Keller, H. A.
	"	21	842	Titaniferous ores in the blast-furnace,	Rossi, A. J.
	"	21	29	Character of slag found near furnaces in Peru,	Pfordte, Otto J.
	"	21	232, 348, 355	Analysis of slag,	Morris, W. H.
	"	21	668	Slag analysis,	Langdon, Wm.
	"	21	844, 846, 851	Analysis of titaniferous slag,	Rossi, A. J.
	Chemiker Zeitung,	16	1596	Analysis of basic Bessemer slag,	Förster, O.
	*I. and S. I.,	2	523	"	"
1893	T. A. I. M. E.,	22	275	Slag from Swedish Bessemer blast-furnace,	Åkerman, R.
	*I. and S. I.,	2	441, 539	"	"
	T. A. I. M. E.,	22	669	Discussion of same,	Campbell, H.H.
	"	22	411	Analysis of open-hearth slag,	"
	Journ. London Chem. Soc.,	61	551	Slag in wrought-iron,	Barrows and Garner
	*S. of M. Quar.,	14	70	"	"
	Journ. Anal. App. Chem.,	7	257	Analysis of slag,	Textor.
	*S. of M. Quar.,	15	65	"	"
1894	Chem. News,	69	303	Ancient slag,	Thompson, W.
	*I. and S. I.,	2	399	"	"
	E. and M. J.,	57		Lead slags,	Austin, T. S.
	T. A. I. M. E.,	23	25	Slag analysis,	Sattman, A., & Homatsch, A.
	E. and M. J.,	57	398	Composition of slags,	Elbers, A. D.
	*Jour. Soc. Chem. Ind.,		394	Analysis of slag,	"
1895	E. and M. J.,	59		Magnesia and sulphur in blast-furnace slags,	"

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I.—Mineralogical Constitution.

Date.	Publication.	Vol.	Page.	Title or Subject.	Author.
1837	Traité des Essai par la Voie Sèche,			General,	Berthier.
1857	Revue Univers des Mines,	1	1st series, p. 210	On artificial minerals,	Gurlt.
1885	Proc. Royal Soc.,		87	Microscopic character of some specimens of devitrified glass,	Henman and Rutley.
1886	Jernkontorets Annalen,	40	232	Mineralogical constitution of slags,	Vogt, J. H. L.
	*I. and S. I.,		317	"	"
	*Neues Jahrbuch,	1	48	"	"
	Zeits f. Berg. u. Hutten W. Sal. in Preuss. Staat,	34	218	Uber die zusammensetzen krystallinische schlacken,	
1889	Neues Jahrbuch,	1	244	Schlacken, mineral bildungen,	Vogt, J. H. L.
	Zeit.f. Krystallographie,	15	652	A fayalite slag,	Firket, A.
	*I. and S. I.,	2	412	"	"
	Amer. Jour. Science,	37	220	Gehlenite in slags,	Diller and Whitfield.
	*I. and S. I.,	1	315	"	"
	Forhandlinger i Videnskapsselskebet i Christiania,	6	1-42	Mica in slag,	Vogt, J. H. L.
	*I. and S. I.,	2	412	"	"
1890	Warszawskija Universitetskija Izwjostijia,	1	1	Fayalite crystals in slag,	Koziorowski, K.
	*Zeit. für Kryst. u Min.,	17	527	"	"
	*I. and S. I.,	1	294	"	"
1891	Les Methodes de Synthese en Mineralogie,	Paris 1891		Mineral,	Meunier, Stanislas
1892	Eng. News,			The latest improvements in photo-micrography,	Pringle, A.
	Mineralbildung in Smeltzmaasen,	Kristianen 1892			Vogt, J. H. L.

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I.—Chemical Analysis.

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1879	T. A. I. M. E.,	8	514	Determination of slag in pig-iron,	Drown, T. M.
1881	E. and M. J.,	31	58, 180	Analyses,	Iles, M. W.
	Dingler's Poly. Jour.,	240	384	Estimation of phosphorus in slag,	Müller, A.
	*I. and S. I,		708	"	"
1884	S. of M. Quar.,	5	351	Decomposition and analysis of slags,	Iles, M. W.
	*Chem. News,			"	"
1885	E. and M. J.,	40	145	Special analysis of glassy slags,	Koehler, W. J.

I.—Chemical Analysis, continued.

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1887	T. A. I. M. E.,	16	89	Determination of silica in carbon,	Jones, Clement.
	Chemiker Zeitung,	11	19	Determination of P_2O_5 in basic slag,	Brunnermann, C.
	*I. and S. I.,	.1	474	"	"
1888	Chem. News,	58	27	Determination of Bi and Li,	Warren, H. N.
	*I. and S I.,	2	335	"	"
1890	Zeit für An. Chem.,	28	219	Solubility of basic slags,	Jensch, E.
	*I. and S. I.,	1	325	"	"
	T. A. I M. E.,	19	131	Method of slag analysis,	Campbell, H.H.
	Bul. de la Soc. Chem.,	2	324	Determination of phosphoric acid,	With, G.
	*I. and S. I.,	1	375	"	"
	Fres. Zeit. An. Chem.,	29	408	Foreign phosphates in slag,	Blum.
	*S. of M. Quar.,	12	64	"	"
1891	Chem. News,	64	275	Phosphoric acid in slag,	Edwards.
	*S. of M. Quar.,	13	180	"	"
	*I. and S. I., 1892,	1	493	"	"
1892	Jour. Chem. Soc.,	41	551	Slag determination in wrought-iron,	Barrows and Turner.
	*I. and S. I.,	2	519	"	"
	Chemiker Zeitung,	15	1397	Detection of adulteration,	Morgan.
	*I. and S. I.,	1	496	"	"
	Zeit. Anal. Chem.,	31	516	Phosphoric acid in basic slags,	Jolles.
	*S. of M. Quar.,	14	165	"	"
	"	13	366	Notes on sampling,	Wood, H. R.
1894	Stahl und Eisen,	14	872	Slag determination in puddled iron,	de Koninck, L. L
	*I. and S. I.,	2	496	"	"
	Jour. An. and App. Ch.,	7	257	Rapid analysis of slag,	Textor, O.
	*I. and S. I.,	2	498	"	"

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1872	T. A. I. M. E.,	1	211	Use of blast-furnace slag,	Egleston, T.
1873	"	2	579	Slag pots,	Keller, H. A.
	"	2	83	Manufacture of compressed stone-bricks,	Bodner, J. J.
	"	2	88	Discussion of same,	Pechin.
1875	"	4	102	Furnace hearths,	Asmuth, Geo.
1876	"	5	114	Expelling mill-cinder from iron rails,	Holley, A. L.
	S. of M. Quar.,	5	161	Utilization of phosphoric slags,	Note.

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1876	E. and M. J.,	21	517	Sugar adulteration.	
				Manufacture of bricks from slag,	
1877	"	24	133	Making slag-blocks,	Woodward, Jas.
1878	"	27	61	Slag-wool,	
1879	"	27	44	Glass from iron-slag.	
	T. A. I. M. E.,	8	39	The working of three hearths at the Cedar Point furnaces,	Witherbee, T. F.
1880	Journ. of the Soc. of Arts, May, 1880,			Utilization of slag,	Wood, Chas.
	*I. and S. I.,		236	"	"
	"		332	Tile-making at the Loire,	
	*E. and M. J.,	30	27	Slag-glass,	
1881	* "	31	269	Slag-concrete substitute for stone,	From London Engineering.
	Dingler's Polyt. Journ.,			Slag for mine-pillars,	
	*I. and S. I.,		673	"	
	T. A. I. M. E.,	10	39	Investigations on the Ore-Knob process. Slag-pots,	Egleston, T.
1882	Min. Res. of U. S.,		161	Utilization of blast-furnace slag,	
	T. A. I. M. E.,	11	61	Slag-wool (note),	Rothwell.
	I. and S. I.,		536	Comparative blast-furnace practice,	Bell, I. L.
	S. of M. Quar.,	3	300	Slags for cement,	
	Stahl und Eisen,	2	303	Utilization of basic slag,	(Note.)
	*I. and S. I.,		787	"	"
1883	E. and M. J.,	35	302	A new plan for utilizing blast-furnace slag,	Elbers, A. D.
	S. of M. Quar,	4	238	Slags for cement,	(Note.)
	E. and M. J.,	38	314	Utilization of basic slags,	Frank, A.
1884	I. and S. I.,		302	Utilization of slags,	(Note.)
	E. and M. J.,	38	23	Paving-blocks made from slag,	"
1885	Oest. Zeit. für B. u. H.,	33	514	Utilization of basic slag,	Blum, L.
	*I. and S. I.,		639	"	"
	*Chem. Zeit.,	10	339	"	"
	*E. and M. J.,	1886			
		42	98	"	"
	Le Fer,	10	1	"	
	*I. and S. I.,		271	"	
	*E. and M. J.,	40	400	"	From several German papers not quoted.
	I. and S. I.,		289	Utilization of blast-furnace slag,	
1886	T. A. I. M. E.,	15	92	Sectional slag- and matte-pot,	Terhune, R. H.
	"	15	685	A tilting ladle-car,	Birkinbine, J.

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1886	*I. and S. I.,	1887			Birkinbine, John.
		1	397	A tilting-ladle car,	
	Genié Civil,	3	6, 7	Utilization of slag,	Chabrand, E.
	*I. and S. I.,		318	"	"
	E. and M. J.,	41	424	Generating steam by slag,	Brotherton.
	"	41	72	Table-ware from slag,	(Note.)
	Chem. Reportorium,	10	25	Slag-cement,	Schumann, C.
	*I. and S. I.,		319, 916	"	"
	*E. and M. J.,	42	402	"	"
	E. and M. J.,	42	418	Blast-furnace slag and slag-cement,	Elbers, A. D.
1887	Cleveland Inst. of Eng., May 7, 1887,			Slag-cement,	Stead, J.
	*I. and S. I.,	1	405	"	"
	E. and M. J.,	44	147, 490	"	
	Chem. Zeit.,	11	55	Utilization of basic Bessemer slag,	Maercker.
	*I. and S. I.,	1	430	"	"
	Iron and Coal Trades Review,	34	479	Grinding basic Bessemer slag,	
	*I. and S. I.,	1	430	"	
	*E. and M. J.,	43	14, 20, 74, 93, 97, 111, 163, 165, 254	Basic slag as fertilizers,	Various.
	E. and M. J.,	43	328, 362	Slag in the manufacture of glass,	Elbers, A. D.
	*E. and M. J.,	44	235, 295	Blast-furnace slag for porcelain-works.	
	Industries,	3	260	Slag for road-metal.	
	*I. and S. I.,	2	293	"	
		44	94, 118,		
	*E. and M. J.,		150	Slag paving-blocks.	
1888	Genié Civil,	12	389	Slag-cement,	Groselande, J.
	*I. and S. I.,	1	314	"	"
	Jernkontorets Annaler,	42	No. 4	Slag as manure,	Odelstjerna.
	*I. and S. I.,	1	315, 340	"	"
	Journ. Brit. Soc. Mining Students,	10	58	Blast-furnace slag for stoning goaves,	Bunning, C. Z.
	*I. and S. I.,	2	217	"	"
	T. A. I. M. E.,	17	84	Phosphate-slag as fertilizer,	Phillips, W. B.
	"	17	389	Slagging-valve for tuyeres,	Cook, Edgar S.
	*I. and S. I.,	2	414	"	"
1889	L'Ecole des Mines et de la Metallurgie,	14	No. 13	Slag-bricks,	Gongé, J.
	*I. and S. I.,	1	315	"	"
	Iron Age,	42	679	Slag paving-stones.	
	*I. and S. I.,	1	316	"	
	B. u. H. Zeit.,	48	150	Pulverizer for basic slag,	Jenisch.
	*I. and S. I.,	1	350	"	"

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1889	Biedermann's Central blatt für Agrikultur Chemie,		228	Comparison of basic slag and superphosphates,	Meissl, E.
	*I. and S. I.,	1	351	"	"
	"	1	349	Basic slag as manure,	Ackman, C. M.
	E. and M. J.,	48	420	Basic slag as fertilizer.	
	Iron Age,	44	121	Slag-grinding mill,	(Note.)
	*I. and S. I.,	2	14	"	"
	Annales Industrielles, 1890		90	Manufacture of slag-cement,	Grosclaude, J.
	*I. and S. I.,	1	296	"	"
	*Dingler's Poly. Journ.,	245	433	"	"
1890	Stahl und Eisen,	10	310	Grinding basic slag,	Wedding, H.
	*I. and S. I.,	1	326	"	"
	Journ. Soc. of Arts,	38	231	Utilization of blast-furnace slags,	Redgrave, G.
	*I. and S I.,	1	294	"	"
	Journ. Soc. Chem. Ind.,	9	67	Utilization of slag for evaporating,	Bell, I. L.
	*I and S. I.,	1	297	"	"
	Trans. Amer. Soc. of Civil Engrs.,	22	147, 190	Slag as railway-ballast,	Trotmann, E.E.
	*I. and S. I.,	1	298	"	"
	Stahl und Eisen,	10	911	Basic slag for manure,	Jensch, E.
	*I. and S. I,	1	325	"	"
	Stahl und Eisen,	10	523	Slag-cement,	Tetmajor.
	*I. and S. I.,	2	760	"	"
	S. of M. Quar.,	12	112	Slag paving-stones at Mansfeldt,	Egleston, T.
	"	12	189	Manufacture of slag-bricks in Montana,	"
	T. A. I. M. E.,	19	350	Cement from blast-furnace slag,	Wedding, H.
	"	19	362	Progress of German practice in metallurgy,	"
	"	19	533	Improvements in steel-works & rolling-mills,	Daelen, P. M.
	"	19	831	British contributions to the metallurgy of iron and steel,	Kitson, Sir Jas.
	*E. and M. J.,	50	274	Cement manufacture,	LeChatelier, M.
	Journ. Soc. Chem. Ind.,			Slag used in evaporating brine,	Bell, I. L.
	*E. and M. J.,	49	292	"	"
	Journ. Soc. of Arts,			Utilization of slag,	Redgrave, R.
	*E. and M. J.,	49	364	"	"
	"	49	586	Slag used in the manufacture of Portland cement,	From Redgrave in Industries.
1891	T. A. I. M. E.,	20	385	Utilization of puddle- and reheating-slags,	Sahlin, Alex.
	*I. and S. I.,	1892 No. 2	414	"	"

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1891	T. A. I. M. E.,	20	584	Note on utilization of puddle- and reheating slags,	Morris, W. H.
	Stahl und Eisen,	11	370	Slag-wagons,	Lührman, F.
	*I. and S. I.,	1	359	"	"
	Stahl und Eisen,	11	553	Slag-tuyere in Germany,	"
	*I. and S. I.,	2	242	"	"
	Iron Age,	48	135	A new form of slag-wagons,	Nare, J. B.
	*I. and S. I.,	2	242	"	"
	Oest. Zeit. für B. u. H. W.,	39	333, 347	Utilization of blast-furnace slag,	Paulovitch, M.
	*I. and S. I.,	2	248	"	"
	Engineer,	71	316	Grinding basic slag,	Zimmer, F.
	*I. and S. I.,	2	281	"	"
1892	Metallurgy of Lead,			Slag-pots for lead-smelting,	Hofman, H. O.
	*E. and M. J.,	54	630	"	"
	Iron Age,	48	117	Blast-furnace slag-wagon,	
	I. and S. I,	2	403	"	
	Proc. Inst. Mech. Engrs., England,		70–97	Utilization and disposal of blast-furnace slag,	Hawden, W.
	*I. and S. I.,	1	409	"	"
	*E. and M. J.,	53	427	"	"
	Mittheilung aus der K. T. V. zu Berlin,		234	Strength of slag-bricks.	
	*I. and S. I.,	1	411	"	"
	Thon. Industre Zeit.,	1		Slag-cement, German production.	
	*I. and S. I.,	1	411	"	
	Dingler's Poly. Journ.,	284	237	Slag-cement,	Pinkenberg.
	*I. and S. I.,	2	439	"	"
	E. and M. J.,	54	57	Utilization of waste-heat of slags,	(Note.)
	Zeit für Ang. Chemie,			Utilization of basic slag as a fertilizer,	von Reis, Dr.
	*E. and M. J.,	54	419	"	"
	T. A. I. M. E.,	21	233	Basic slag as a fertilizer,	Morris, Wm. H.
	*I. and S. I.,	2	459	"	"
1893	S. of M. Quar.,	15	108	A plant for granulating slag,	Terhune, R. H.
	T. A. I. M. E.,	22	20	Slag-cements,	Le Chatelier, H.
	"	21	71	Desilverization of lead-slags,	Kellar, H. A.
	*E. and M. J.,	56	104	"	"
	Oest. Zeit. für B. u. H. W.,	41	201	Slag-cement and bricks,	Toldt, F.
	*I. and S. I.,	2	441	"	"
	E. and M. J.,	56	52	Using heat from slags.	
	"	56	593	Slag-brick manufacture in Germany,	(Note.)

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1894	Journ. Frank. Inst.,	137	184–189	Slag-cement,	Mahon, P. W.
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	*E. and M. J.,	57	150	Slag-wool,	(Note.)
	E. and M. J.,	57	392	Economic use of slag,	Elbers, A. D.
	"	58	56	Utilization of waste-heat,	Howell and Ashcraft.
	*I. and S. I.,	2	393	"	"
	Iron Age,	54	255–256	Hawdon's slag-machine,	Hawdon.
	*I. and S. I.,	2	393	"	"
	Chem. Zeit.,	18	1511	Basic slag,	Wagner, P.
	*I and S. I.,	2	425	"	"

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Metallurgical Laboratory, Columbia College, School of Mines.
July 1, 1895.

ABSTRACTS.

ANALYTICAL CHEMISTRY, BY ELWYN WALLER, PH.D.

Potassium bi-iodate as a Reagent. Meineke (*Chem. Ztg.*, xix., 2). This salt is now manufactured pure. KIO_3, HIO_3 or KHI_2O_6.

In presence of acid with excess of KI the reaction is:

$$KHI_2O_6 + 10KI + 11HCl = 11KCl + 6H_2O + 6I_2.$$

In neutral solution the reaction is:

$$6KHI_2O_6 + 5KI = 11KIO_3 + 3I_2 + 3H_2O.$$

The difference in the action affords a method for determining the proportion of free acid present in a given solution. CO_2 should be excluded as much as possible, as it slowly effects the same change.

A solution of KHI_2O_6 after reduction by Na_2SO_3 may be used to standardize $AgNO_3$ solutions.

With phenolphthalein as indicator, the salt can also be used for standardizing normal (etc.), alkali solutions, the HIO_3 in the molecule acting as a free acid.

H_2O_2 for Separations of Metals. Jannasch and Röttgen. Tenth paper (*Zts. f. Anorg. Chem.*, viii., 302). Pouring the acid solution of the metals into ammoniacal solution of H_2O_2 was found to be the most satisfactory method of procedure.

Bi from Cd. Bi is at once precipitated, clean, as yellow hydrated bismuth peroxide.

Pb from Cd. Pb is readily precipitated as PbO_2. The precipitate adheres strongly to the filter paper, and is best dissolved off by moistening with hot dilute, HNO_3, and then adding some H_2O_2 solution.

A second precipitation may sometimes be desirable for perfect separation.

Mn from Cu. The MnO_2 which separates always carries some Cu with it. By increasing the amount of ammonia, and after mixing the solutions, digesting for fifteen minutes on the water-bath, and washing with H_2O_2 and ammonia, a precipitate containing only 0.5 per cent. Cu was obtained. On redissolving and reprecipitating, practically pure MnO_2 resulted. SiO_2, if present, will remain in the ammonia solution.

Mn from Cd. Readily accomplished.

Standardizing Sulphuric Acid. Shiver (*J. Am. Chem. Soc.*, xvii., 351). Weinig has proposed to check the standard of normal or fractional normal H_2SO_4 by neutralizing with ammonia, evaporating to dryness, and weighing the $(NH_4)_2SO_4$ after drying at 115–120° C. The author finds that the evaporation causes some loss of ammonia by dissociation of the salt. He finds, however, that by evaporating with excess of ammonia, then moistening the solid residue with a little strong

ammonia and finally drying, a perfectly neutral $(NH_4)_2SO_4$ is obtained, from the weight of which, the strength of the solution may be calculated.

Determining Potassium as the Platino-Chloride. Winton (*J. Am. Chem. Soc.*, xvii., 453). When the aqueous potassium solution was so dilute that no precipitate was formed on adding the Pt solution, and it was subsequently evaporated, treated with alcohol, etc., the K_2PtCl_6 was obtained pure. If a concentrated K solution received the addition of Pt solution there was an occlusion of some of the mother liquor, which was not removed unless drying was effected at 160° C. The factors 0.30688 for KCl and 0.1939 for K_2O should be used.

Qualitative Separation of the Alkaline Earths. Baubigny (*Bull. Soc. Chim.*, xiii., 326). Precipitate by NH_4Cl and $(NH_4)_2CO_3$ leaving Mg in solution. Dissolve the carbonates in as little HCl as possible, add an alkaline acetate to neutralize free HCl. Precipitate Ba out by $K_2Cr_2O_7$. (K_2CrO_4 may precipitate $SrCrO_4$ out also). Add K_2SO_4 solution containing 2.5 grammes K_2SO_4 per litre. This precipitates only Sr after stirring and standing for some little time. In the filtrate separate Ca by $(NH_4)_2CO_3$ to get it away from the chromates. Dissolve in very little HCl and add $NH_4C_2H_3O_2$. Then add a considerable excess of NH_4Cl, solid or in concentrated solution and follow up with K_4FeCy_6. A double calcium potassium ferrocyanide, insoluble in strong NH_4Cl will form, slowly at first, but increasing in amount rapidly. The reaction is quite delicate. Sr gives nothing similar, but Ba does.

Iron and Alumina in Phosphates. Hess (*Zts. Angew. Chem.*, 1894, 679). Glaser's acetate method (*Fres. Zts. Anal. Chem.*, xxxi., 383), was tested. The precipitate with $NH_4C_2H_3O_2$ at 70° was seldom constant in composition and never consisted of $Al_2(PO_4)_2$ and $Fe_2(PO_4)_2$. Also, Ca was seldom absent from the precipitate. By repeated precipitation with acid $(NH_4)_2C_2H_3O_2$ with addition of H_3PO_4, precipitates free from Ca could be obtained. With this modification the results were more quickly and accurately gained, than with the alcohol method.

Iron in its Ores. Mixer and Dubois (*J. Am. Chem. Soc.*, xvii., 405), a method used in the Lake Superior region. Solutions used:

A.—1 pound $SnCl_2$ dissolved in 1 pound HCl (gr. 1.2) with water, finally diluted to 2 litres.

B.—HCl of sp. gr., 1.1.

C.—Saturated solution of $HgCl_2$.

D.—160 grammes $MnSO_4$, in 1750 c.c. water, to which are added 330 c.c. of phosphoric acid (syrup) (sp. gr., 1.7) and 320 c.c. of H_2SO_4 (sp. gr., 1.84.)

E.—250 grammes $K_2Mn_2O_8$ in a carboy (about 44 litres). The strength should be such that 1 c.c. = about 2 per cent. Standardize with an ore of known content in iron.

Process. About 0.5 grammes of ore, is treated in a lipless beaker (No.O.) with 2.5 c.c. of A and 10 c.c. of B. Boil gently on an iron plate until solution is effected. After solution, $SnCl_2$ (A) is run in, drop

by drop, until all Fe is reduced—as shown by the color. Wash down the sides of the beaker, and add 5 c.c. of C. Rinse immediately into a 500 c.c. beaker, containing 6 to 8 c.c. of D and about 100 c.c. of water. Titrate with F. Comparative results, which are quoted, indicate that the method is very accurate.

Determination of Manganese. Thomas (*J. Am. Chem. Soc.*, xvii., 341). The method of Low. (*vid.* QUARTERLY, xiv., 256), was found to give results uniformly high. Volhard's method gave results about 0.5 per cent. low, but was more uniform.

Electrolytic Determination of Manganese. Gröger (*Zts. f. Angew. Chem.*, 1895, 253). For small amounts it was found better to treat the precipitated MnO_2 (?) with HCl and KI and determine the Mn by $Na_2S_2O_3$ titration of the liberated I. The precipitate, however, when reckoned as MnO_2 indicated only 94 to 96 per cent. of the actual amount of Mn present. For exact determination it must be converted to anhydrous MnS, which makes the method unsatisfactorily elaborate.

Volumetric for Nickel. Lecoeuvre (*Rev. Univ. des Mines et Met.*, xxviii., No. 3). The method depends on the precipitation and re-solution of $NiCy_2$ in KCy when working in a slightly ammoniacal solution. A 10 per cent. KCy solution is used. The neutralized solution of Ni receives the addition of a few c.c. of 5 per cent. ammonia, and then the KCy solution is run in with stirring, until the last drop alters the turbid liquid to a clear yellowish solution. The KCy is standardized by $(NH_4)_2\ Ni(SO_4)_2$. One c.c. is usually equivalent to about 0.022 Ni.

Volumetric for Zinc. Stone (*J. Am. Chem. Soc.*, xvii., 473). The method of Schultz and Low was found unsatisfactory (*vid.* QUARTERLY, xiv., p. 40, also p. 65). Titrating Mn and Zn together with ferrocyanide, and titrating Mn in a separate portion by Volhard's method ($K_2Mn_2O_8$) was found to give good results.

The standard solutions used are:

K_4FeCy_6, 30 grammes per litre. Standarize by use of Zn or Mn solutions containing known amounts,—lots containing about 0.1 gramme of the metal.

$K_2Mn_2O_8$, 1.99 grammes per litre. Standardize by metallic Fe. The Fe value multiplied by 0.294646 gives Mn value. One c.c. of this solution should equal about 0.001 gramme Mn.

In acid solution (not over 1 c.c. conc. HCl in 14 c.c. of solution) the Mn precipitate is Mn_3FeCy_6 (3 Mn = 4 Zn). The indicator used is very dilute $Co(No_3)_2$ solution on a porcelain plate, the drops being allowed only to touch—*not to mix*. A faint greenish line at the junction of the two drops showing *immediately*, marks the end reaction. The titration must be conducted in about 100 to 150 c.c. bulk at *ordinary* temperatures, as it is influenced by heating.

Sulphide ores should be dissolved with HCl and $KClO_3$. Zinc oxides, carbonates and silicates should be dissolved in HCl, and oxidized by $KClO_3$. Franklinite or rhodonite must be fused with Na_2CO_3, evaporated to dryness with HCl, and the solution then boiled with addition of some $KClO_3$.

A solution having been obtained in which the Fe has been certainly converted to ferric, and which preferably contains rather small amounts of free acid, Cu, if present, must be separated by means of metallic Pb, or both Cu and Pb may be separated by metallic Al. Pb alone does not need to be removed. (Cd if present must be removed by H_2S and the solution afterwards oxidized).

Fe and Al are to be separated by $BaCO_3$ in cold solution, added until the precipitate curdles. (The $BaCO_3$ must be free from NH_4 salts. $Ba(OH)_2$ alkaline carbonates, etc., and needs to be especially prepared by warming a sample (ammonia free) for some time with 2 per cent. of $BaCl_2$ in solution.) Filter, and take aliquot portions of the solution for titration.

The Volhard titration for Mn should be conducted in a solution nearly boiling (bulk about 200 c.c.)

The ferrocyanide titration should be performed in a solution slightly acid with HCl (5 c.c. in about 100 c.c. of the solution).

The color darkens at first, and then suddenly becomes lighter as more K_4FeCy_6 is run in. After this point is passed, the "spot" tests with $Co(NO_3)_2$ solution must begin to be made.

A dozen analyses quoted show that the method affords a satisfactory agreement with the gravimetric results.

Determining Copper. Dulin (*J. Am. Chem. Soc.*, xvii., 346). An examination was made of, 1. KCy method. 2. Iodide method. 3. Electrolysis. The conclusions reached are that the iodide method (after separating out the Cu by Al foil) gives results 0.1 to 0.3 too high, the electrolytic method results too high or too low according to the amount of other metals present, and that the cyanide method gives results which are practically correct.

Iodide Method for Copper. Process of Low (*Eng. and Min. Jour.*, lix., 124). To obtain the Cu free from Fe and other substances which might interfere with the accuracy of this method, the metal is precipitated from the solutions by means of Al foil. The ore is decomposed by use of aqua regia, H_2SO_4 added, and the solution evaporated to fumes, and then on dilution, $PbSO_4$ and gangue may be filtered off. Boiling this solution for six or seven minutes on a strip of Al foil, will precipitate all the Cu, which is filtered off, washed and dissolved in HNO_3. About 0.5 gramme $KClO_3$ is added to fully oxidize any As present, and then after boiling down, the solution is ready for treatment with ammonia (after which it should be boiled), then acetic, and then KI, followed by titration of the free I in the usual manner. The method is described in Furman's *Manual of Assaying.*

Qualitative Separation of Copper and Cadmium. Cushman (*Am. Chem. Jour.*, xvii., 379). It was found that CdS is quite soluble in saturated solution of alkaline chlorides in presence of a little free HCl. H_2S will fail to precipitate Cd from a mixture of 2 c.c. of solution of Cd salt to which have been added 10 c.c. saturated NaCl solution and a few drops of HCl. Dilution, or the addition of dilute ammonia, brings it down at once. The method recommended is to acidify slightly 2 c.c. of the solution containing both Cd and Cu with HCl, then to add

20 c.c. of saturated solution of NaCl, warm, and saturate with H_2S. Then filter through a dry filter into a dry test-tube. To the clear filtrate add water little by little. A yellow ring of CdS will form at the junction of the two liquids. Diluted ammonia may be used instead of water, giving a more delicate test. Pb and Bi, however, act in a somewhat similar manner to Cd, and, if present, may obscure the reaction.

Arsenic in Presence of Selenium. Dawydow (*Chem. Ztg.*, xix.). Neither Bettendorf's test ($SuCl_2$) nor the Marsh test will serve to detect small amounts of As when Se is present. In the first case the reaction is masked, in the second the formation of a mirror is prevented. It is recommended, therefore, to first precipitate out with H_2S, and to extract As by $(NH_4)_2CO_3$, and from the solution to obtain a solution of As suitable for the application of these tests.

Determining Antimony. Brunck (*Fres. Zts. Anal. Chem.*, xxxiv., 171). As it has been asserted that Sb_2O_4 is somewhat volatile, at the temperature of ignition, an investigation was made as to this point. It was found that Sb_2O_4 was not volatile when ignited in an open crucible. When, however, the crucible was covered, some volatilization of Sb_2O_3 occurred, apparently because the edge of the cover diverted some reducing gases into the crucible.

The mode of management recommended is to rinse the sulphide (tri or penta) into a small porcelain capsule, dissolve in $(NH_4)_2S$, dry, oxidize with HNO_3, heat off H_2SO_4, etc., cautiously, and finally ignite strongly. By this means the use of filter paper is avoided.

Acidimetric Titration of Molybdic Acid. Seubert and Pollard (*Zts. f. Anorg. Chem.*, viii., 296). This question is of importance in connection with methods of determining P_2O_5 which are coming into prominence. The best indicator was found to be phenolphthalein, although litmus gave fair results, rosolic acid moderately fair, lakmoid uncertain, and helianthin, congo red and cochineal were quite useless.

The sensitiveness of phenolphthalein to CO_2, which might be absorbed by the alkaline solutions used, rendered it necessary to work rapidly and in other ways to arrange the operations so as to minimize this possible error. Good results were obtained with sublimed MoO_3, pure crystallized $H_2MoO_4.H_2O$., $K_2Mo_8O_{10}$., MoO_2Cl_2., and $(NH_4)_6Mo_7O_{24}.4H_2O$. With the ammonium salt an excess of standard NaOH was added, and the NH_3 boiled out before titrating back.

Determining Bromine in Presence of Chlorine. Neuse (*Zts. Angew. Chem.*, 1895, 13). The free elements are passed into a solution containing a known amount of KI (excess). An aliquot portion is then titrated with hyposulphite, and another portion is evaporated to dryness, dried at 160° to 180° C., and then weighed. The loss by conversion of KI to KBr and KCl, combined with the results obtained in the titration, gives a basis for the calculations of the proportions of Br and Cl present.

Decomposition of Silicates. Jaunasch (*Zts. Anorg. Chem.*, viii., 364), $PbCO_3$ is used, obtained by precipitating $Pb(C_2H_3O_2)_2$ with a calculated

amount of $(NH_4)_2CO_3$ and carefully washing and drying. 10 to 12 times as much $PbCO_3$ as substance is used, and the fusing effected in a platinum crucible, with a flame burning without any bright tip. Heat moderately for 15 to 20 minutes until most of the CO_2 is expelled; then more strongly for 10 to 15 minutes. The cake is removed from the crucible after cooling, disintegrated with HNO_3, evaporated over the water-bath to dryness, HNO_3 added, and again evaporated; then taken up with HNO_3, and after warming, the SiO_2 is filtered off and washed. The major part of the Pb is separated from the filtrate by HCl, and the filtrate therefrom is again evaporated to dryness to recover the little remaining SiO_2. In the filtrate the residual Pb is separated by H_2S, and the solution is then to be examined for the other constituents of the silicate.

Liquid Carbonic Acid. Grünhut (*Chem. Ztg.*, xix., 505 and 555). Reference is made to Fleck's observation that when impure HCl has been used in generating the gas, $AsCl_3$ *may* exist in the gas. Aside from this, impurities of iron, glycerin and other organic matters have been found. Some samples give a brownish color to conc. H_2SO_4 and slowly destroy permanganate. An ill-smelling liquid containing these substances is frequently found in the cylinders after the CO_2 has been used out. The source of the glycerin is not quite clear.

Ammonium Magnesium Phosphate. Neubauer (*Zts. Angew. Chem.*, 1894, 678). Addition of $(NH_4)_2SO_4$, when precipitating, will cause the precipitate to burn white readily when it comes to ignition.

Phosphoric Acid by the Citrate Method. Runyan and Wiley (*J. Am. Chem. Soc.*, xvii., 513). This method is called by Blair the "Acetate Method." It consists in precipitating the magnesium compound in presence of iron, etc., the ferric and aluminic phosphates being prevented from separating by the addition of citric acid. The authors find it satisfactory when 10 per cent. of P_2O_5 or over is present. For the determination of smaller amounts, they add a measured amount of a solution of phosphate of known strength, and then deduct the amount known to have been added from the weights obtained.

Phosphoric Acid Determination by Manganese. Lindemann and Motten (*Bull. Soc. Chem.*, xiii., 523). The plan is to separate P_2O_5 as $MnNH_4PO_4$, to convert the Mn into MnO_2, and then to determine indirectly by iodometry. The first difficulty encountered was that to get a crystalline precipitate, the presence of an excess of phosphate is usually necessary. It was found, however, that if one adds to a solution containing about 0.100 gramme of P_2O_5. 10 c.c. of a 20 per cent. NH_4Cl solution, 10 c.c. of ammonia, 25 c.c. of $(NH_4)_3C_6H_5O_7$ (150 grammes of citric acid in litre), and finally 25 c.c. of a 25 per cent. solution of crystallized $MnSO_4$, a solution is obtained, which, though at first colored, becomes colorless on boiling, and in five minutes deposits all the P_2O_5 as NH_4MnPO_4. Cool, filter and wash with a half per cent. solution of NH_4Cl. Dissolve in HCl, dilute to 250 c.c., add 1 to 4 c.c. of H_2O_2 solution, then 20 c.c. of 10 per cent. KOH, and boil to destroy H_2O_2. Then add 20 c.c. of 10 per cent. KI, and titrate with standard $Na_2S_2O_3$. It is assumed that Mn_6O_{11} is formed by the H_2O_2.

Water Soluble Phosphoric Acid. Kalmann and Meissels (*Fres. Zts. f. Anal. Chem.*, xxxiii., 764). The solution from 20 grammes of superphosphate is diluted to one litre. 100 c.c. of the clear solution is made exactly neutral to methyl orange by use of N/2 NaOH. Phenolphthalein is then added, and the amount of N/2 NaOH to exactly neutralize is noted *a*. The formation of a precipitate renders the recognition of the end reaction a little difficult. Another 100 c.c. of the superphosphate solution is shaken in a 250 c.c. flask with N/2 NaOH in not too small excess, the flask filled to the mark, well mixed, and then filtered. To 100 c.c. of the filtrate add phenolphthalein, neutralize with N/2 acid, then add methyl orange, and titrate exactly with half normal acid. Multiply the c.c. used in the last case by 2.5 to get the value for the 100 c.c. of superphosphate solution *b*. The arithmetical mean between *a* and *b*, multiplied by 0.0355 gives grammes of P_2O_5 in 100 c.c. of the superphosphate solution (2 grammes). The reaction involved in the last is:

$$3\ CaH_4(PO_4)_2 + 8NaOH = Ca_3(PO_4)_2 + 4Na_2HPO_4 + 8H_2O.$$

Na_2HPO_4 is neutral to phenolphthalein.
NaH_2PO_4 is neutral to methyl orange.

Sulphur in Illuminating Gas. Collan (*Fres. Zts. f. Anal. Chem.*, xxxiv., 148). By passing the products of combustion through standard H_2CrO_4 solution, it was found that about 93 per cent. of the S present appears as SO_2. When these products were passed through an alkaline solution, almost all of the SO_2 was converted to sulphate.

Sulphur in Petroleum. Hensler (*Zts. f. Angew. Chem.*, 1895, 285), describes an apparatus for this purpose, constructed on the same plan as the apparatus for S in illuminating gas. The petroleum is burned in a lamp which is weighed before and after the experiment. This lamp is placed under a bell, the air supplied being passed through a tube of soda lime. Above the bell is a glass chamber, in which is adjusted a small funnel, the stem of which is bent to one side so as to deliver through a tube communicating with a flask outside. Over the funnel is fixed a reversed condenser, through which is allowed to trickle a solution of $K_2Mn_2O_8$; the solution is only allowed to wet the sides of the tube, an exhaust being applied at the top of the condenser to draw in the air necessary for the combustion. The products of combustion are thus oxidized by contact with the $K_2Mn_2O_8$, and collected in the flask, in the contents of which the S may be determined at the end of the operation by well known methods.

Small Amounts of Sulphides in Presence of Precipitated Sulphur. Fresenius (*Zts. Anal. Chem.*, xxxiii., 573). Often on passing H_2S, small amounts of CdS, SnS_2 As_2S_3, etc., may be obscured by the presence of separated S. On adding benzene or protroleum ether and shaking well, the S is dissolved, and the precipitate may be seen if any is present.

Examining Fuming Sulphuric Acid. Lunge (*Zts. f. Angew. Chem.*, 1895, 221), calls attention to the fact that in these analyses error is often

committed by assuming that methyl orange (the best indicator for the purpose), shows its neutral tint with Na_2SO_3, whereas it is neutral at $NaHSO_3$. The method consists in diluting 3 to 4 grammes of the acid up to 500 c.c., and determining acidity on one portion of 100 c.c., and on another the amount of SO_2 by titration with tenth normal iodine. From the latter result the SO_2 is calculated, and after calculating the acidity due thereto, the remaining acidity is reckoned to SO_3. In a case occurring in actual practice which he cites, where 2.43 of SO_2 was present, the error was over 8 per cent of SO_3.

Barium Sulphate. Richards and Parker (*Zts. f. Anorg. Chem.* viii., 413). Investigation as to the occlusion of $BaCl_2$ in the precipitate. The conclusions are:

1. The occlusion of $BaCl_2$ by $BaSO_4$ produces marked errors.
2. The occlusion is more decided in concentrated than in dilute solutions, greater in the presence than in the absence of HCl, and also greater when the sulphate is added to the Ba solution than the reverse.
3. Under the ordinary conditions of careful precipitation in presence of a small amount of free acid, the errors resulting from occlusion are very nearly compensated by the solubility of the $BaSO_4$ in water or acid. This solubility must always be taken into account in careful work.
4. The error resulting from occlusion can be more exactly corrected by determining the Cl in the precipitate, and deducting the calculated equivalent of $BaCl_2$ from the weight of the whole precipitate.

Selenium in Meteoric Iron. Warren (*Chem. News.*, lxxi., 249). Ten grammes of filings were mixed with flour of sulphur, the mixture placed in a combustion tube, and heated to redness. Oxygen was passed into the tube; at the other end, connection was made with a number of bulb tubes containing distilled water. The solution containing suspended Se was heated to 80° F., placed in a platinum dish, dried in an air bath, and the Se weighed. A blank was also carried through with the Se employed. In six different samples, 0.04 to 0.23 per cent. of Se was found.

Moisture in Coal. Grittner (*Zts. f. Angew. Chem.*, 1895, 309). Drying in an atmosphere of H, the containing tube being connected with a $CaCl_2$ tube, gave results nearly 1 per cent. higher than drying in the ordinary way (exposed to oxidation). The gain of the $CaCl_2$ tube was practically identical with the loss of the coal. Illuminating gas, instead of H, was not so satisfactory.

Water in Silicates. Jaunasch and Weingarten (*Zts. f. Anorg. Chem.*, viii., 352). The method by fusion with PbO in a tube, though satisfactory in many cases, gave untrustworthy and irregular results with silicates containing much calcium. The method found to be most generally applicable was fusion in a specially bent combustion tube, along with anhydrous borax, in a current of dry air. The mode of preparing the dry borax is given. If fluorides are present, an admixture of $PbCrO_4$ or PbO will be necessary.

BULLETIN OF ALUMNI AND COLLEGE NEWS.

The Annual Dinner of the Association of the Alumni of the School of Mines was held in New York May 10, 1895. It was considered one of the most successful and enthusiastic of the dinners ever held. The classes were grouped at small tables in the large dining-room at Delmonico's, so that the effect was that of a series of class reunions at the various tables, and sociability and acquaintance was secured and promoted.

The central thought of the evening was the munificent and splendid gift to the College by its President, Seth Low, of the sum of one million dollars, to be devoted to the erection of the beautiful library building on the new site. At the table of honor upon the dais, sat the President of the Association, Mr. W. B. Parsons, of '82, and with him President Low, Mr. H. M. Howe, of Boston, and Mr. McKim, the architect, on one side, and on the other side, Mr. Geo. S. Morison, Mr. T. C. Martin, and Profs. Burr and Ware. When the presiding officer, in introducing the speakers referred to the library and to President Low's gift to the College for it, the entire hundred men broke out into repeated cheers and acclamations, with waving of napery and applause. It was a most stirring scene, and when President Low rose to respond, it was with a voice shaking with the depth of feeling he could not restrain. An address of congratulation and appreciation was read by Mr. Wm. Allen Smith, of '68, and adopted by a rising vote. Prof. Munroe, as chairman of the Association's Committee, reported on enlisting the effort of the members and their friends for the work of the School upon the new site. Copies of the elegant report of this committee were distributed to those present at the dinner. The other speakers were Mr. Geo. S. Morison, President of the American Society of Civil Engineers, Mr. Henry M. Howe, Past-President of the Institute of Mining Engineers, Mr. McKim, upon the architectural problem of the new college site, Mr. T. C. Martin, President of the *Electrical Engineer* Association, and editor-in-chief, and by Prof. Ware, upon the architectural fellowships. Mr. Eckley B. Coxe, Past-President of the American Society of Mechanical Engineers, and Prof. C. F. Chandler, were to have been present, but were detained by illness. Music was furnished by a mandolin orchestra, and Messrs Ricketts, Foyé and Morgan, as the Dinner Committee, were most heartily to be congratulated. One hundred and nine persons sat down to the tables.—F. R. H.

Department of Mechanical Engineering.

The most interesting feature of the half-year in this department has been the research work in the mechanical laboratory by students of the Class of 1895, in connection with their graduating theses. The subjects have covered a broad field. One branch was an investigation into the friction of brick upon brick and stone, and of stone upon stone under

the considerable loads per square inch which could be brought by the testing machines. Another research was into the relation of bearing area to shearing area in the framing joint where a rafter joins a tie, with different angles between the rafter and the tie. A third was the comparative relation between the actual and theoretical consumption of steam in a small steam engine, together with a comparison between the brake and indicated horse-power. Other mechanical theses of the year have been a calibration of a transmitting dynamometer, a re-design of a water-works pumping engine, and a test of an air compressor, driven dry, wet and jacketed. These assignments have given great interest to the year's work.

In the vacation class-work, the students have visited the great telescopic gas-holder in process of erection at the plant of the East River Gas Co., and the usual visit to the Bethlehem Iron Co.

ELECTRICAL ENGINEERING DEPARTMENT.

This department has occupied jointly with the department of Mechanics a new laboratory in the basement of the President's house, in which advanced work in electrical measurements and original investigation in alternating current phenomena have been carried on.

Three members of the graduating class selected electro-chemical subjects for their theses, and have obtained very interesting results in connection with the electro-deposition of alloys and selective electrolysis. This work is based upon Professor Crocker's article on the "Theory of Electro-metallurgy," which appeared in the January issue of the QUARTERLY. It is believed that these experiments, which were carried on in the assay laboratory, are the beginning of an important development to be secured by the co-operation of the departments of Electrical Engineering and Chemistry, since Electro-Chemistry is now generally admitted to be a branch in which great progress is likely to be made in the near future. Four other members of the graduating class, under the direction of Mr. Sever, made a series of tests on one of the Brooklyn electric roads, to determine the effect of the brakes and the track and atmospheric resistances at various speeds up to 45 miles per hour, which is an unusually high speed for a "trolley" car. An interesting feature of these tests is the fact that the actual power exerted by the motor is found by making separate Prony brake tests of the power developed by it with various numbers of volts and amperes of current.

DEPARTMENT OF BIOLOGY.

Dr. Bashford Dean has made his third spring excursion after embryos of the ganoid fishes, on this occasion to Ocomowoc, Wisconsin. He reached there just in time, and has procured a full series of the eggs of *Amia*. Last season he procured the garpike (*Lepidosteus*) and the season before the sturgeon (*Acipenser*). This enables him to complete a comparative study of the embryology of the entire group of ganoids, an opportunity which has never been equalled before. His work, *Fishes Living and Fossil*, will be dedicated to Dr. Newberry.

Professor Wilson's recent studies upon Fertilization will soon appear in the form of an Atlas from the University press, illustrated with unique microphotographs taken by Dr. Edward Leaming of the P. & S.

Professor Osborn has appointed Mr. W. D. Matthew assistant in Vertebrate Palæontology in the American Museum, from July 1st, and has sent Mr. Irving (Columbia, B.A., 1896) into the field as assistant to Dr. J. L. Wortman. The Museum expedition this year passes from northeastern Utah around through Brown's Park into the Washakie basin of southeastern Wyoming.

GEOLOGICAL DEPARTMENT.

The Saturday excursions of the Geological Department have been continued through the spring, and opportunities have been given to the classes to visit the marble quarries at Tuckahoe, the brownstone quarries at Belleville, N. J., the fire-clay pits at Perth Amboy, and the marls at Atlantic Highlands. Toward the close of the term, the pressure of examinations became so severe that the usual concluding trip to see the terminal moraine at Glen Cove was omitted. These trips are an important part of the instruction, because they enable the students to see typical exposures of the strata that are being described in the regular courses.

As the Summer School of Practical Mining is to be located this year in Central City, Colorado, the accompanying field work in geology will also be done in that State. Golden has been selected by Professor Kemp as the most suitable place because from it, as a centre, the class can be taken over the granite ridges of the front range of the Rocky Mountains, and then across the steeply dipping strata of the early and later Mesozoic rocks that rest upon them. In the Dakota group there are important beds of fireclay and attendant industries, and in the Laramie there are coal mines on almost vertical strata. In addition, there is a fine mesa of basalt forming Table mountain, which is cut in two by Clear Creek. The basalt rests upon beds of volcanic tuff that are abundantly provided with plant remains. Near the coal beds are also other fossil plants of earlier date. The basalt of the two Table mountains is a famous locality for minerals of the zeolite group. It is probable that after the regular work closes, a part of the class will accompany Professor Kemp to the new gold-mining camp at Cripple Creek. Professor Kemp will meet the class at Golden on July 8th. Professor Kemp expects to spend some time in June continuing field-work, already begun, upon the granite intrusions along the north shore of the Sound, and in August and September to resume the regular work in the Adirondacks that has been in progress for some years past. As the result of this work last September, some twenty-five sections of the great ore-bodies of magnetite at Mineville, near Port Henry, were obtained. They are drawn parallel with one another, and exactly 100 feet apart. They have been transferred to parallel panes of thin plate glass, and set in a box-frame, so that they make a very vivid picture of the relations of the ore and its walls of rock. The model is in the Geological Museum. The necessary means for its completion were generously provided by the trustees. The model will be the basis of a later contribution on the geology of the ores.

Mr. Hollick has continued his studies upon the specimens of Cretaceous plants from Staten Island, Long Island, and Martha's Vineyard. The Staten Island collections have been supplemented by additions re-

cently made on Saturdays and other free days of the week. The U. S. Geological Survey has turned over to Mr. Hollick its collections from the above regions, and has arranged to bring out his results as a survey monograph. This will enable him to suitably illustrate the flora with quarto plates. Mr. Hollick will continue field-work during the summer on the most easterly exposures.

The collections made by Mr. van Ingen and Mr. W. D. Matthew from the lower Cambrian near St. John, N. B., and which have been studied up the past winter by Mr. G. F. Matthew, have proved of the greatest interest and importance. They have enabled Mr. Matthew to identify an entirely new fauna at the base of the Cambrian, that he has called the Protolenus Fauna, from a genus of trilobites that is a prominent member of it. It is as yet uncertain whether or not it is older than the Olenellus Fauna that has been hitherto thought to be the oldest assemblage of early forms of life, but dealing, as it does, with the earliest of well preserved and well organized forms of life, the paper is of exceptional importance. It has just been issued in the *Transactions* of the New York Academy of Sciences, and will form No. XXVIII. of the contributions of the Geological Department. The fossils will come to the college museum by previous arrangement with Mr. Matthew, to whom, as already stated in these columns in earlier issues of this year, the college is under great obligations.

During June Mr. van Ingen will be in the field with Mr. T. G. White in the Lake Champlain valley, in connection with the latter's doctorate work. Very interesting results have already accrued from the preliminary collection, made last summer. Mr. van Ingen will be engaged for the greater part of the vacation in working up in the museum the results of his collections made in previous summers. It is hoped to have the matter ready for printing in the early fall. Some valuable points in the relations of the faunas of the Siluro-Devonian strata will be brought out.

Mr. W. D. Matthew, who has been Fellow in Geology during the last two years, has completed the work for his doctor's degree, and has been appointed assistant palæontologist at the American Museum of Natural History. His work will lie in vertebrate palæontology under Professor Osborn.

The Geological Department will be represented at the meeting of the American Association for the Advancement of Science and the Geological Society of America, in Springfield, Mass., in August. Papers are in preparation by at least two of the staff.

During Professor Moses' absence the coming year, Professor Kemp will act as managing editor of the SCHOOL OF MINES QUARTERLY.

THE DEPARTMENT OF MATHEMATICS.

This department will gain much from three appointments recently made. Through the co-operation of Barnard College, a new professorship has been established, the incumbent of which, besides giving courses at Barnard, is to assist in the graduate work at Columbia. In the place of the adjunct professorship formerly held by Professor Goodwin, two new tutorships have been established. To the new professorship has been appointed Dr. Frank Nelson Cole, and to the tutorships, Dr. J. Brace Chittenden and Mr. John E. Hill.

Professor Cole was graduated from Harvard in 1882. He then went abroad, and was a student for three years, 1882–1885, at Leipsic, under Professor Felix Kline. Returning to Harvard, he was appointed a lecturer on Mathematics. In 1886 he took the degree of Ph.D. at Harvard, and in 1887 he was appointed to a tutorship. His health breaking down, he was compelled to give up his work. In 1888 he accepted an instructorship at the University of Michigan, was made acting assistant professor in 1889, and assistant professor in 1890.

The following is a list of Professor Cole's publications:

(1) "A Contribution to the Theory of the General Equation of the Sixth Degree" (Doctor's Dissertation).—*American Journal of Mathematics*, vol. 8, pp. 265–286. Baltimore, 1886.

(2) "Klein's Ikosaeder" (Review).—*Am. Jour. Math.*, vol. 9, pp. 45–61. Baltimore, 1886.

(3) "On Rotations in Space of Four Dimensions."—*Am. Jour. Math.*, vol. 12, pp. 191–210. Baltimore, 1890.

(4) "The Linear Functions of a Complex Variable."—*Annals of Mathematics*, vol. 5, pp. 121–176. Charlottesville, Va., June, 1890.

(5) "The Theory of Substitutions and its Applications to Algebra." By Dr. Eugene Netto, Professor of Mathematics in the University of Giessen. Revised by the author, and translated with his permission. Ann Arbor, Mich., The Register Publishing Co., 1892, 8vo., pp. xii.–301.

(6) "Klein's Modular Functions" (Review).—*Bulletin of the New York Mathematical Society*, vol. 1, pp. 105–120. New York, February, 1892.

(7) "Simple Groups from Order 201 to Order 500.—*Am. Jour. Math.*, vol. 14, pp. 378–388. Baltimore, 1892.

(8) "On Groups Whose Orders are Products of Three Prime Factors." (Together with J. W. Glover.)—*Am. Jour. Math.*, vol. 15, pp. 191–220. Baltimore, 1893.

(9) "Simple Groups as far as Order 660."—*Am. Jour. Math.*, vol. 15, pp. 303–315. Baltimore, 1893.

(10) "Note on the Substitution Groups of Six, Seven, and Eight Letters."—*Bulletin*, New York Math. Society, vol. 2, pp. 184–190. New York, May, 1893.

(11) "The Transitive Substitution Groups of Nine Letters."—*Bulletin*, New York Math. Society, vol. 2, pp. 250–258. New York, July, 1893.

(12) "List of Substitution Groups of Nine Letters."—*Quarterly Journal of Pure and Applied Mathematics*, vol. 26, pp. 372–388. London, 1893.

(13) "List of the Transitive Substitution Groups of Ten and of Eleven Letters."—*Quar. Jour. Math.*, vol. 27, pp. 39–50. London, May, 1894.

(14) "On Simple Groups." Read at the Mathematical Congress at Chicago, 1893. In press.

Dr. Chittenden was graduated from Worcester Polytechnic Institute with the degree of B.S. in 1888. He then entered Harvard, obtaining the degree of A.B. in 1889, and that of A.M. in 1890. In 1891 he received a fellowship from Harvard, and went to Germany, studying for four semesters at Konigsberg under Prof. F. Lindemann. He took

the degree of Ph.D. there in 1893. His dissertation was published in English. It is "A Presentation of the Theory of Hermite's Form of Lame's Equation." Leipsic, B. G. Teubner, 1893. 8vo., pp. 85.

Mr. Hill was graduated from Yale with the degree of Ph.B in 1885. He was a resident engineer of the Chicago, Milwaukee, and St. Paul Railway, 1885–1888; Professor of Mathematics at the Louisville Military Academy, 1888–1889; Superintendent of Schools at Pleasantville, New York, 1889–1890: and Professor of Mathematics and Civil Engineering at Highland Park College, Des Moines, Iowa, 1890–1892. Since September, 1892, he has held a fellowship in mathematics at Clark University, Worcester, Mass., and is about to take the degree of Ph.D. from that institution. His dissertation is "On Quintic Surfaces."

THE SUMMER SCHOOL OF PRACTICAL MINING will be held this year in the vicinity of Central City, Colorado, where the class will assemble on June 3d.

This is one of the older gold districts of the West, and comprises a number of large well-worked mines, which will afford excellent opportunities for study. It is intended, as usual, to devote four weeks to routine work at one or two mines, then one week of short visits to other properties in the immediate vicinity, and finally a sixth week, under the leadership of the Professor of Geology, will be spent in field geological work. In connection with the mine work, an underground survey occupying several days will be made by squads of four men each. The class will consist of fourteen members.

DEPARTMENT OF CIVIL ENGINEERING.

The past year's work in this department exhibits several characteristics which, it is hoped and believed, are significant of a future successful development. Several important subjects have been extended, and their places in the course of study so rearranged as to improve the efficiency of the work done, and afford much more time for this work in the fourth year. The subject of water supply and irrigation, embodying but little advanced analytic work, has been moved back into the second year, while that portion of the subject of foundations which embraces the treatment of earth pressure and retaining walls, masonry towers, chimneys, and arches, is now given in the second session of the third year. The subject of hydraulics, involving advanced treatment of all questions relating to the velocity in and discharge through orifices and pipes or other conduits, the gauging of pipes and streams, the power of waterfalls, and the hydraulics of rivers and irrigation in other lands, extends through the first session of the fourth year. In connection with these changes, there has been a considerably enlarged amount of actual engineering design work, of a high degree of excellence, done in the afternoon hours. These and other developments of an essential character are being so made as to be consistent with the broadest professional view of civil engineering, and so as ultimately to afford to students in the department facilities for special studies in sanitary engineering, the engineering of public works, hydraulic engineering, geodesy, and in bridge and railroad work, including motive power.

The beginnings of a hydraulic laboratory have been made during the past year by the acquisition of several important pieces of apparatus, and it is hoped that the department may possess the complete plant after removal to the new site of the university.

A fairly well equipped cement-testing laboratory has been organized and used for routine work by members of the third and fourth classes, as well as for much interesting work of investigation still in progress.

The department has also been the fortunate recipient from Prof. Thomas Egleston of a large number of fine photographic views of the Spring Valley Dam, in California, during the progress of its construction, acknowledgment for which is hereby made.

OBITUARY.

STANCLIFF BAZEN DOWNES, class of '82 and member of the Alumni Association, School of Mines, died suddenly, April 21, 1895, from pneumonia and heart failure, succeeding an attack of measles. He was the only son of Anson Treat and Eliza Bazen Downes, and was born in New York City December 5, 1859. He received his early education at the Anthon Grammar School, afterward entering Columbia College School of Mines, and graduated in 1882 as a civil engineer. He rendered valuable assistance in preparing a set of tax maps of the annexed district of the Park Department, spending several years in thoroughly searching the Westchester county records, at White Plains, to obtain reliable information for the work. He also was connected with engineering work in the Twenty-third and Twenty-fourth Wards of New York City. In 1889, after returning from Europe with the party of United Engineering Societies, he was engaged on a system of drainage at his ancestral home at Milford, Conn., the house there being built in 1639 by his ancestor, Thomas Buckingham, and remaining in possession of descendants since. This work of drainage not only improved his own land, but adjacent property within a radius of a half-mile, for which improvement the neighbors were highly appreciative. In the summer of 1894 he planned a unique system of water supply for lawn and garden by means of hydraulic rams, with original additions. He early showed talent for invention, as a unique design of scales, a game-table, a wind-gauge and other articles testify. Every room in his home contains pieces of his handiwork. He kept a work-room well filled with tools, among which he spent much of his leisure time. He was a man of loyal and true character; a dutiful son and devoted brother. He was of retiring disposition, and, though socially popular, was not a club-man. Besides this association, he was a member of the Young Men's Christian Association, the Loyal Legion Temperance Society, the American Society of Civil Engineers, the Museum of Art, the New York Genealogical and Biographical Society, the Sons of American Revolution, and the Society of Colonial Wars.

The interment took place at Milford, Conn., the former home of Governor Robert Treat, from whom Mr. Downes was lineally descended.

LISTS

OF THE

ALUMNI OF COLUMBIA COLLEGE SCHOOL OF MINES

1895.

MEMBERS OF THE ALUMNI ASSOCIATION AND OTHER GRADUATES
DETECTING ERRORS IN THE SUCCEEDING LISTS
WILL PLEASE SEND CORRECTIONS TO

PROF. F. R. HUTTON,
SECRETARY,
COLUMBIA COLLEGE SCHOOL OF MINES,
OR TO
No. 12 WEST THIRTY-FIRST STREET,
NEW YORK CITY.

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(Revised to May, 1895.)

OFFICERS

CONSTITUTING THE

BOARD OF MANAGERS

OF THE

ALUMNI ASSOCIATION OF THE SCHOOL OF MINES

1895.

President,
WILLIAM BARCLAY PARSONS, '82.
22 William St., N. Y.

Vice-President,
JAMES FURMAN KEMP.
Columbia College, N. Y.

Secretary,
F. R. HUTTON, '76.
Columbia College, N. Y.

Treasurer,
LEA McILVAINE LUQUER, '87.
Columbia College, N. Y.

MANAGERS.

Terms expire 1895.	Group.	Terms expire 1896.
A. W. HALE, '67.	I.	J. C. F. RANDOLPH, '69.
ARTHUR H. ELLIOTT, '81.	II.	NATH. L. BRITTON, '79.
R. W. HILDRETH, '85.	III.	LEA McI. LUQUER, '87.
GEO. R. TUSKA, '91.	IV.	J. M. HEWLETT, '90.

NOTE.—Correspondence concerning dues and other clerical details of the work of the Association may be conveniently addressed to MR. FRANCIS W. HOADLEY, Assistant to the Secretary and Treasurer, No. 12 West 31st St., New York City.

LIST No. 1.

Contains the names of all Graduates and Members of the Alumni Association grouped by classes from the beginning. The details as to Residence and Professional Occupation are given in the second or alphabetical list for convenient reference.

(Revised to May, 1895.)

CLASS LIST

OF

GRADUATES AND MEMBERS

OF THE

ASSOCIATION OF THE ALUMNI.

[NOTE.—Where the name is followed by a date, it denotes that the person is no longer living, and the date is the year of the death.]

1867.

Adams, J. M., 1892.
Bridgham, S. W.
Bronson, E. S.
Brown, F. G.
Church, J. A.
Cornwall, H. B.
Giddings, E. E.
Gracie, C. K., 1891.
Hale, A. W.
Harding, G. E.*
Harmer, T. H.
Heath, F. M.
Tuttle, W. W.
Van Lennep, D.

1868.

Barnard, A. P.
Baxter, G. S.
Carson, J. P.
Chester, A. H.
Coursen, G. H.
Geer, G. J., Jr.
Hanna, G. B.
MacMartin, A., 1881.
Melliss, D. E.*
Moffatt, E. S., 1893.
Parsons, G. H.
Pennington, J. P.*
Pistor, W.
Platt, C. S.
Robertson, K.
Shack, A. P.
Schermerhorn, F. A.
Smith, L.
Smith, W. A.
Stalknecht, F.
Van Arsdale, W. H.
Wheeler, M. D., 1889.

1869.

Blossom, T. M., 1876.
Bruckman, F.
Campbell, A. C.
Delafield, A. F.*
Hooker, W. A.
Huntington, C.
Irving, R. D., 1888.
Jenney, W. P.
Munroe, H. S.
Nettre, L. R.
Newton, H., 1877.
Potter, W. B.
Randolph, J. C. F.

1870.

Haight, O., 1891.
Ingersoll, W. H.
Knapp, J. A.
Lilienthal, J. L., 1893.
Lindsley, S.
Parrot, E. M.
Terhune, R. H.
Van Wagenen, T. F.
Waller, E.

---

* Associate.

1871.

Fales, W. E. S.
Goldschmidt, S. A.
Gordon, J.
Ricketts, P. de P.
Riggs, G. W.
Roberts, G. S.
Robertson, R. S., Jr.

1872.

Austen, P. T.
Jenney, F., 1876.
McDowell, F. H.
Sloane, T. O'C.
Wendt, A. F., 1893.

1873.

Canfield, F. A.
Colton, C. A.
Mott, H. A.
Webb, H. W.
Williams, J. T.

1874.

Allen, C. S.
Benedict, W. de L.
Cameron, J. G. M., 1889.
Ledoux, A. R.*
Lillie, S. M.
Murray, G.
Olcott, E. E.
Rees, B. F.
Rhodes, F. B. F.
Williams, F. H.

1875.

Ihlseng, M. C.
Iles, M. W.
Jackson, C. E.
Joy, D. A., 1888.
Lamson, R., 1876.
Leavens, H. W.
Macy, A., 1891.
Noyes, W. S.
Pfister, P. C.
Putnam, B. T.. 1886.
Rees, J. K.
Rolker, C. M.
Russell, S. H., 1889.
Stewart, H.
Thompson, M. S.
Tucker, J. H.
Vanderpoel, F.
Wells, J. S. C.
Wetmore, E. A.
Wright, A. A.

1876.

Austin, T. S.
Bruen, F. E., 1884.
Cornwall, G. R.
Craven, F. C., 1890.
Foote, H. C., 1888.
Garrison, E. H.
Gratacap, L. P.
Hall, R. W.
Hamilton, S., Jr.
Holbrook, F. N.
Hoyt, W. L.
Hunt, F. F.
Hutton, F. R.
King, C.
Lord, N. W.
Love, E. G.
Maghee, J. H.
Morewood, H. F.
O'Grady, J. W., 1890.
Randolph, J. F.
Ross, W. C.
Schneider, A. F.
Tilden, G. C.
Van Blarcom, E. C.
Walbridge, A. C., 1892.
Wardlaw, J. R., 1891.

1877.

Barros, L. de S.
Barus, C.
Beard, J. T.
Behr, E.
Buckley, C. R.
Cady, L. B.
Canfield, A. C.
Cauldwell, J. B.
Clark, H. G., 1881.
Colby, C. E.
Constant, C. L.
Cornell, G. B.

* Associate.

Floyd, F. W.
Helleberg, F. S., 1883.
Hildreth, W. E.
Ihlseng, A. O.
Jordao, J. N. P.
Kelly, W.
Mackintosh, J. B., 1891.
Martin, E. W.
Murphy, J. G.
Nichols, R.
Norris, D. H.
Priest, J. R., 1880.
Radford, W. H.
Reed, S. A.
Rogers, C. L.
Sage, E. E.
Smeaton, W. H.
Smythe, R. M.
Thacher, A.
Van Boskerck, R. W.
Waterbury, C. R.

1878.

Adams, W. J.
Benjamin, M.
Blydenburgh, C. E.
Downing, O. P.
Drummond, I. W.
Eliot, W. G.
Fernekes, A., 1884.
Haas, H. L.
Hasegewa, Y.
Hodges, H. A., 1883.
Holden, E. H.
Hollis, W.
Johnson, E. M.
Johnson, G. H.
Karr, C. P.
Booraem, R. E.
Brinkerhoff, G. C.
Butler, W. P.
Lawrence, B. B.
Lyman, F.
Martin, N.
McCulloh, E. A.
Morewood, G. B.
Morris, G. W.
Munsell, C. E.
Murphy, H. N.
Nambu, K.
Newberry, S. B.
Cushman, A. R.
Davis, J. W.
Devereux, W. B.
Noyes, J. A.
Olmstead, O. F., 1881.
Owen, F. N.
Palmer, C. E.
Parker, R. A.
Pazos, V. F.
Perry, N. W.
Strieby, W.
Willis, B.

1879.

Bolton, R.
Britton, N. L.
Cloud, L. G.
Cornwall, H. C.
Deluze, L. P.
Eastwick, G. S.
Haffen, L. F.
Harker, C. S.
Hathaway, N.
Hollerith, H.
Hollick, C. A.
Johnson, I. B.
Johnston, R. A.
Koch, E. C.
Leggett, T. H.
Ludlow, E.
Marsh, C. W.
Mathis, T. S.
Mayer, R. E.
Merwin, H. J.
Milliken, G. F.
Munroe, O. M.
Neftel, K.
Nesmith, J.
Noble, C. M.
Reed, W. B. S.
Rhodes, R. D.
Rutherford, F. M.
Sheldon, G. H., 1889.
Starr, H. F.
Stewart, F. B., 1879.
Stone, G. C.
Suydam, J. R., Jr.
Williams, G. W.

1880.

Beebe, A. L.
Benjamin, F. P., 1893.
Browning, F. D., 1885.
Brugman, W. F.
Butler, N.
Churchill, A. D.
Clark, E. P.
Elliott, W.
Engel, L. G.
Francke, R. O.
Garlichs, H.
Greene, W. U.
Greenleaf, J. L.
Hallock, A. P.
Hendricks, H. H.
Hooper, L. M.
Hopke, T. M.
Hudson, E. H.

Klepetko, F.
Kunhardt, W. B.
Mattison, J. G.
Meissner, C. A.
Merritt, J. H.
Navarro, J. A.
Parker, A. McC.
Parks, J. R.
Robinson, H. A.
Ruttman, F.
Singer, G.
Singer, G. H.
Smalley, W. B., 1886.
Smith, M.
Tonnelé, T.
Torrey, C. H.
Walker, J., Jr.
Wheeler, H. A.

1881.

Andresen, C. A.
Aschman, F. T.
Bleecker, C. P.
Braschi, V. M.
Bush, E. R.
Chazal, P. E.
Colby, A. L.
Curtis, C. G.
Douglas, E. M.
Dunham, E. K.
Elliott, A. H.
Furman, H. V. F.
Griswold, W. T.
Hemmer, F. A.
Judd, C. B.
Leary, D. J.
LeBoutillier, C.
Ledoux, A. D.
Little, W. P.
Meserole, W. M.
Neymann, P.
O'Connor, M. J.
O'Connor, T. D.
Pitkin, L.
Raymer, G. S.
Richmond, W. T.
Roberts, A. C.
Sawyer, C. P.
Share, W. W.
Starr, C. D.
Stearns, T. B.
Swain, A. E.
Tuttle, E. G.
Van Sinderen, A. H.
Vulté, H. T.
Wiechmann, F. G.
Williams, W. F.
Wilson, H. M.

1882.

Calman, A.
Conant, T. P., 1891.
Cooper, W. H.
Crocker, F. B.
Dougherty, O. V., 1889.
Downes, S. B.
Downs, W. F.
Emrich, A. F., 1893.
Falk, D. B.
Feuchtwanger, H.
Fitch, C. L.
Going, C. B.
Hill, W.
Illig, W. C., 1894.
Joüet, C. H.
Mesa, A. E.
Moses, A. J.
Oothout, E. A., 1894.
Page, W. S.
Parsons, W. B.
Payne, C. Q.
Porter, J. B.
Powers, C. V. V.
Sands, F.
Shumway, W. A., 1892.
Staunton, W. F.
Stockwell, N. S., 1888.
Toucey, D. B.
Traphagen, F. W.
Vondy, R. H.
Wainwright, J. H.
Wanier, A. G.
Ward, N. R.
White, W. S.
Wilson, W. A.
Wittmack, C. A.
Young, E. L.

1883.

Abeel, G. H.
Adams, R.
Ayestas, A.
Balch, S. W.
Banks, J. H.
Bardwell, A. F.
Brereton, T. J.
Brewster, H. D.
Browning, J. H. B.*
Bullman, C.
Carrère, J. M.
Channing, J. P.
Endicott, G., 1889.
Ferrer, C. F.
Ferris, J. C.
Fiallos, E. C.
Haasis, D. F.
Humbert, W. S.

* Associate.

Lilliendahl, A. W.
MacTeague, J. J.
McKenna, C. F.
Oxnard, J. G.
Painter, J. G.
Paraga, C. F.
Peele, R., Jr.
Powell, F.
Randolph, E.
Renault, G.
Rich, J. M.
Richardson, J. C.
Ridsdale, T. W.
Suter, G. A.
Tibbals, G. A.
Tower, A. E.
Walker, A. L.
Weed, W. H.

1884.

Adams, W. C.
Alden, H. C.
Baldwin, W. M.
Barnard, E. C.
Barratt, E. G.
Bodelsen, O.
Brinley, J. R.
Bryce, W.
Buckingham, F. E.
Burritt, W. W.
Corcoran, J. T.
Del Calvo, F.
Duncan, W. P., 1889.
Dusenberry, W. T.
Easton, L. C.
Fahys, G. E.
Fitch, J. H.
Fitzgerald, G. E.
Fowler, S. S.
Glover, C. G., 1888.
Gosling, E. B.
Griffin, S. P.
Gross, L. N.
Horn, J. T.
Kemp, J. F.
Lamb, A. J.
Luttgen, E.
McGenniss, J. W., Jr., 1890.
McKim, R. A.
McLoughlin, C. S.
Miller, C. W.
Moeller, W., 1887.
Moran, D. E.
Morgan, W. F.
Mulford, R.
Napier, A. H.
Newberry, W. E.
Newbrough, W.
Nolan, F.
Northrop, J. I., 1891.
Nye, A. C.
Painter, C. A.
Pearis, C. F.
Pellew, C. E.
Post, A. S.
Powers, L. J.
Proctor, W. R.
Reckhardt, D. W.
Roeser, F.
Rood, R. G.
Rowland, C. B.
Rupp, P., Jr.
Schoney, E., 1888.
Sherman, F. D.
Slack, C. G.
Smedberg, H. A.
Snook, T. E.
Speyers, C. L.
Tibbals, S. G.
Value, B. R.
Walbridge, F. K.
Wood, G. E.

1885.

Amy, E. J. H.
Barkley, H. F.
Bemis, F. P.
Brennan, A. J.
Bush, W. F.
Cary, G.
Clark, F. S.
Cozzens, H.
Crowell, C. B.
Detwiller, C. H.
Doolittle, C. H.
Dwight, A. S.
Eddie, E. C.
Engelhardt, E. N.
Graff, C. E.
Hart, B.
Hawkes, E. McD.
Hildreth, R. W.
Hollis, H. L.
Huntington, F. W.
Ingram, E. L.
Johnson, A. G.
Lacombe, C. F.
Lee, G. B.
Mannheim, P. A. L.
Marié, L.
Meyer, H. H. B.
Merrill, F. J. H.
Miller, C. L.
Moldehnke, R. G. G.
Noble, L. S.
Norris, R. V. A.
Page, G. S.
Pierce, H. N.
Polledo, Y. Y.
Sanders, W. E.
Shope, H. B.
Starek, E.
Struthers, J.
Thomas, F. M.
Titus, W. H.
Van Cortlandt, E. N.
Watson, F. M.
Whitman, E. P.
Wiltsie, E. A.
Woolson, I. H.

1886.

Agramonte, E., Jr.
Agramonte, J. C.
Bell, H. M., Jr.
Berry, W. G.
Casey, E. P.
Conant, H. D.
Edwards, R. M.
Frankfield, E.
Good, G. McC. H.
Horne, W. D.
Howe, E.
Janeway, J. H.
Jenks, A. W.
Kissam, H. S.
Lederle, E. J.
Lee, H. C.
Newhouse, E. L.
Norton, L. H.
Ormsbee, J. J.
Osterheld, T. W.
Peck, S. B.
Porter, H. H., Jr.
Ryon, A. M.
Spooner, A. N.
Stodder, R. H., 1887.
Stuart, W. H.
Thompson, H. C.
Trowbridge, S. B. P.
Van Brunt, A. H.
Von Nardroff, E. R.
Wallace, W. J.
Wheatley, J. Y.
Wilson, C. E.

1887.

Aldridge, W. H.
Appleby, W. R.
Bellinger, H. P.
Bien, J. R.
Burns, A. L.
Burns, E. Z.
Butler, W. C.
Church, E. D.
Cole, H. M.
Congdon, E. A.
Cox, J. S., Jr.
Darwin, H. G.
Davis, C. H.
Donnell, H. E.
Ferguson, W. C. A.
Gage, S. E.
Goldsmith, B. B.
Gudeman, E.
Heinsheimer, A. M.
Huntting, H. O.
Jacobs, D. M.
Jacobs, S. J.
Jeup, B. J. T.
Lahey, J.
Lahey, R.
Luquer, L. McI.
Lusk, G.
MacKaye, H. S.
Mannheim, H. C.
Marsh, J. R.
Middleton, J.
Moeller, R.
Muller, G.
Nichols, H. P.
Primelles, J. A.
Restrepo, C.
Rice, G. S.
Rowland, G.
Rutherford, L. H.
Schieffelin, W. J.
Seligman, J. G.
Simonds, F. M.
Slade, R. E.
Stanton, F. McM.
Staunton, J. A., Jr.
Stevens, A.
Tower, F. W.
Trask, G. F. D.
Tyler, W. L.
Warner, J. L.
Wels, P. O.
Wertheimer, L.

1888.

Allen, R. L.
Appleby, J. S.
Baker, G. L.
Bartlett, F. R.
Bechstein, C. A.
Beckwith, C. E.
Berry, G.
Brewster, H. D.*
Browning, J. H. B.*
Colt, S. B.
Comstock, C. N.
Dodge, F. D.
Dodsworth, W. A.
Dow, A. W.
Fisher, W.
Frank, J. W.
Gardner, W. D.
Hebert, O. B.
Hopkc, F. E., 1890.
Jones, W. D.
Koen, J. J.
Lenox, L. R.
Lipps, H., Jr.
McIlvaine, A. R.
Maclay, J.
Morgan, L.
Miller, R. P.
Munoz del Monte, A. C.
Parker, O. B., 1891.
Parsons, H.
Percival, G. S., 1892.
Perkins, T. S.
Schumann, C. H.
Shriver, H. T.
Smith, F. P.
Smyth, C. H., Jr.
Stoughton, A. A.
Taylor, J. B.
Tucker, A.
Van Dyck, E.
Van Volkenburgh, E.
Volckening, G. J.

* Associate.

1889.

Wampold, L.
Ward, D. W.
Atha, H. G.
Berry, G.
Brown, R. G.
Cramer, S. W.*
Cromwell, J. W.
Denton, F. W.
Dresser, D. LeR.
Eastwick, E. P.
Eilers, K. E.
Ellis, A. V. H.
Escobar, F.
Fearn, P. LeR.
Fowler, A. C.
Freedman, W. H.
Gifford, S. D.
Griffith, V. C.
Griggs, W. E.
Guiterman, E. W.
Harrington, T. H.
Harris, E.
Heinze, F. A.
Holt, M. B.
Ives, A. S.
Jopling, R. F.
Luquer, T. T. P.
Mahony, A. S.
Mapes, C. H.
Mason, C. S., 1889.
Massa, C. G.
Matthews, C. T.
Monell, J. T.
Mosley, R. K.
Oseransky, I. H.
Piez, C.
Post, A. Van Z.
Preston, W. E.
Provost, A. J., Jr.
Provot, G.
Raymond, R. M.
Raynor, R.
Rogers, O. L.
Schroeder, J. L.
Skidmore, S. T.
Small, F. M.
Smith, A.
Smith, F. M.
Stoughton, C. W.
Waters, G. S.
Wedekind, E. H.
Weekes, E. F., 1893.
Weeks, W. H.
Whitlock, H. P.

1890.

Andrews, S. W.
Beckwith, G. A.
Behlen, H.
Betts, R. T.
Black, A. L.
Blake, E. M.
Book, D. D.
Bradley, S. R.
Buckland, W. A.
Cairns, F. I.
Carson, J.
Clark, D. L.
Clayton, W. R.
Colton, F. G.
Connell, H. R.
Coykendall, T. C.
Davis, W. M.
Deghneé, J. A.
Douglas, J. S.
Ferguson, G. A.
Fisher, L. W.
Foyé, A. E.
Gudewill, C. E.
Gould, E. C.
Hart, C. H.
Hewlett, J. M.
Hicks, G. J., 1891.
Hinman, B. C.
Hooper, F. C.
Hoyt, J. S.
Hurlburt, E. D., Jr.
Jarmulowsky, M.
Jones, T. J.
Kohn, R. D.
Korn, L.
Levy, A. L.
Lichtenstein, E. G.
Lowndes, W. S.
McKleroy, W. H.
Mann, H. B.
Massa, L. F.
Meikleham, T. M. R.
Montenegro, M. R.
Parker, H. C.
Portuondo, J.
Post, W. S.
St. John, T. M.
Steers, J. R.
Thorne, W. L.
Wainright, R. T.
Warren, C. P.
Welch, A. McM.
Welsh, H. F.

1891.

Anderson, Geo.
Bliss, C. P.
Blossom, F.
Boecklin, W.
Boyd, R. C.
Brosnan, F. X.
Cristy, E. B.
Eberhardt, Wm. G.
Goodwin, E.
Hawley, J. F.
Holter, N. B.
Hornbostel, H. F.
Keeler, F. S.
Kinsey, F. W.
Langthorn, J. S.*

* Associate.

Leary, Geo.
Lilliendahl, F. A.
Livingston, A. R.
Mahl, J. T.
Miller, E. H.
Mora, M. L.
Raymond, A.
Skinner, E.
Strout, W. A.
Thomas, F. C.
Totten, G. O., Jr.
Tucker, S. A.
Tuska, G. R.
Warren, L.
Watson, R. B.
Wiener, Wm.

1892.

Ansbacher, L. A.
Anthon, A.*
Bergen, C. H.
Bolles, R.
Burden, H., 2d.
Casamajor, G. H.
Clark, Edmund. *
Clarke, W. C.
Dolan, C. F.
Dufourcq, E. L.
Durham, E. B.
Dutcher, B. H.
Fenner, C. N.
Friedman, S.
Gillette, H. P.
Granger, A. D.
Hay, A.
Herckenrath, W. A.
Jackson, O.
Kletchka, J. J.
Livingston, G.
Longacre, L. B.
Lord, F. R.
McIlhiney, P. C.
McKinlay, J. B.
Meisel, F. C. A.
Merz, E.
Pierce, F. E.
Reckhart, G. F.
Ries, H.
Rosenthal, A.
Savage, S. M.
Southard, G. C.
Temple, S. J.
Towart, J.
VanIngen, D. A.
Werner, H. C.
White, R. D.
Windecker, C. N.
Windolph, A. P.

1893.

Agramonte, I. E.
Aldrich, C. H.
Ayres, W. C.
Behrman, G. W.
Bossange, E. R.
Brooks, W. F.
Canfield, M. C.
Clark, G. H.
Covell, W. S.
Foster, R. G.
Gregory, L. E.
Hankinson, A. W.
Harte, C. R.
Haskell, H. G.
Hoyt, R.
Hyde, F. S.
Jones, J. E.
Kurtz, E. L.
Langmuir, A. C.
Liebmann, A.
McKee, S. H.
Macy, V. E.
Malukoff, A. J.
Matthew, W. D.
Newton, T. M.
Oakes, J. C.
Pederson, F. M.
Pomeroy, W. A.
Post, R. B.
Prince, A. D.
Provot, F. A.
Reynolds, M. T.
Robinson, F. G.
Schroter, G. A.
Smith, H. A.
Thompson, S. C.
Tilghman, H. A.
Tuttle, W.

1894.

Acken, B. A.
Black, Adolph.
Bogert, M. T.
Chapman, A. W.
Clark, Leroy.
Cokefair, F. A.
Emery, H. G.
Fellows, Wm. K.
Folger, E. P.
Frisbee, H. D.
Fuentes, Paul.
Greene, D. J.
Haas, E. F.
Hamilton, F. C.
Hanson, R. C.
Harold, A. P.
Jacobs, H. A.
Jones, E. M.
Kastner, J. C.
Leeming, T. L.
Libaire, E. W.
McNeil, C. R.
Masters, H. K.
Messiter, E. H.

* Associate.

Meyer, Joffe.
Mears, G. K.
Morris, B. W., Jr.
Murchison, K. M.
Munroe, M.
Osterberg, Max.
Pope, J. R.
Prince, J. L.
Rennard, J. C.
Rittenhouse, C. T.
Searle, C. D.
Seldner, R.
Self, E. D.
Sherman, G. F. G.
Smith, W. F.
Steinam, J. L.
Stratton, Alex.
Taintor, W. N.
Tennille, G. F.
Tompkins, J. A.
Vail, L. H.
Vanderbilt, W. D.
Vatable, J. J.
Walker H. V.
Ware, F. B.
Westervelt, W. J.
White, T. G.

LIST No. 2.

This list embraces the members of the Alumni Association of the School of Mines under the Constitution of that body. It is urged that all graduates of the School should list themselves under this group. Names not found here are grouped in List No. 3, which includes graduates who are not also members. All graduates are requested to try to make and keep this list correct and accurate.

(Revised to May, 1895.)

MEMBERS

OF THE

ALUMNI ASSOCIATION OF THE SCHOOL OF MINES.

A.

ABEEL, GEORGE HOWARD, E.M., ... 1883.
Box 638, Hurley, Iron Co., Wis.
1883–1884, Chemist Iron Cliffs Co., Negaunee, Mich. 1885–1888, Assistant Manager Cliffs Co., Negaunee, Mich. 1886–1887, Supt. Negaunee Gas Light Co., Mich. 1888–1889, Manager Ironton Iron Mining Co., Bessemer, Mich. 1888–1889, Agent Pilgrim Mining Co., Bessemer, Mich. 1889, Supervisor Bessemer Township, Gogebic Co., Mich. 1889–1892, Agent Ruby Iron Mining Co., Bessemer, Mich. 1888 to date, General Manager of Montreal River Iron Mining Co., Hurley, Wis. 1892 to date, Vice-President First National Bank, Hurley, Wis. 1892 to date, Vice-President Wisconsin Mining Supply Co., Hurley, Wis. 1893, Vice-President and General Manager Section 33 Iron Mining Co., Hurley, Wis. 1894, Consulting Engineer Newport Iron Mining Co., Supervisor, Town of Vaughn.

ADAMS, RANDOLPH, E.M., ... 1883.
Broken Hill, N. S. Wales, Australia.
1884–87, Assistant Superintendent and Superintendent of the Silver King Mine, Silver King, Arizona. 1887–91, engaged in Australia as Mining Superintendent and Mining Expert, and now Manager of the Central Broken Hill Mine, Broken Hill, N. S. Wales, Australia.

AGRAMONTE, EMILIO, C.E., ... 1886.
110 Lexington Avenue, New, York City.
Engineer Department of Public Works.

ALDRIDGE, WALTER HULL, E.M., ... 1887.
Manager United Smelting and Refining Co., East Helena, Montana.
Beginning July, 1887, Assayer at Colorado Smelting Co., Pueblo. At different times, Chemist of Colorado Smelting Co., Pueblo. August, 1890–91, Assistant Superintendent and Metallurgist of Colorado Smelting Co., Pueblo. Assistant Manager United Smelting and Refining Co. 1893, Manager as above.

ALLEN, CHAS. SUMNER, PH.B., M.D., ... 1874.
Practicing Physician.

ALLEN, ROBERT LAWRENCE, A.M., E.M., . . . 1888.
102 Cambridge Place, Brooklyn, N. Y.

AMY, ERNEST JULIUS HYACINTHE, A.B., E.M., . . 1885.
General Manager, San Juan S. and M. Co., Durango, Colo.

1885–1886, Chemist and Assayer at works of the San Juan and N. Y. M. and S. Co., at Durango, Colo., with the exception of three months' professional visit to Old Mexico. 1886–1887, Assistant Manager of the San Juan and N. Y. M. and S. Co., at Durango, Colo. 1887–1888, Manager of the Hazelton Mountain Mining Co., at Silverton, Colo. 1888 to April 1, 1890, Assistant Manager of Works of the San Juan Smelting and Mining Co., at Durango, Colo. (the S. J. S. and M. Co. being formed by the consolidation of the S. J. and N. Y. M. and S. Co., of Durango and the Hazelton Mt. Mfg. Co., of Silverton, Colo.). Since April 1, 1890, General Manager of the San Juan Smelting and Mining Co., at Durango, Colo.

ANDREWS, SAMUEL WAKEMAN, JR., PH.B., . . . 1890.
Andrews, Waters & Sherwin, 35 W. Forty-second Street, New York City.

1890–1891, Designing with Tiffany Glass and Decorating Co., New York. 1891 to date, member of above firm.

ANSBACHER, LOUIS ADOLPH, PH.B., ... 1892.
A. B. Ansbacher & Co., 4 Murray St, and 17 W. 52d Street, New York City.

ANTHON, ARCHIBALD (Associate), ... 1892.
13 West 35th St., New York City.

APPLEBY, W. R., A.B. (Associate), ... 1887.
Professor of Mining and Metallurgy, University of Minnesota, and 911 Fifth St., S. E., Minneapolis, Minn.; also 29 Bentley Avenue, Jersey City, N. J.

ATHA, HENRY GURNEY, PH.B., ... 1889.
756 High Street, Newark, N. J.

AUSTEN, PETER TOWNSEND, PH.B., PH.D., . . . 1872.
Polytechnic Institute and 99 Livingston St., Brooklyn, N. Y.

1878–1880, Assistant Professor of Analytical Chemistry, Rutgers College. 1880–1889, Professor of General and Applied Chemistry, Rutgers College. 1891, Superintendent Manufactories of W. J. Matheson & Co., limited, Ravenswood, N. Y. 1892, General Manager, Ledoux Chemical Laboratory. 1893, Professor of Chemistry, Polytechnic Institute, Brooklyn, N. Y.

AUSTIN, THOMAS SEPTIMUS, E.M., ... 1876.
Chihuahua Mining Co., Chihuahua, Mexico.

1877–1878, in Cuba as Chemist. 1879–1880, Assayer Germania Smelting Co. 1880–1890, Superintendent Rio Grande Smelting Co., Socorro, N. M.

B.

BAKER, GEORGE LEWIS, PH.B., ... 1888.
Address unknown.

BALCH, SAMUEL WEED, E.M., ... 1883.
Box 333, Yonkers, N. Y., and 41 Wall Street, New York City.

1883–1884, Otis Elevator Co. 1884–1886, Mowing Machines. 1886–1889, Garvin Machine Co., Tools and Special Machinery. 1889 to date, General consulting practice as Mechanical Expert and Patent Attorney. Specialty, Difficult Mechanical Problems.

BALDWIN, WILLIAM M., PH.B. (Life Member), . . 1884.
55 Beekman St., N. Y. City, and Garden City, Queens Co., N. Y.
Since 1885, Chemist for the New York Dye Wood Extract and Chemical Co. Since 1888, Vice-President of the above corporation, and at present having charge of their manufacturing department.

BANKS, JOHN HENRY, E.M., ... 1883.
104 John Street, New York City, and Boonton, N. J.
1883–1885, Chemist with Ledoux & Ricketts, New York. 1885–1891, Private Assistant to Prof. Ricketts, School of Mines, New York, in general analytical, metallurgical and mining engineering work. 1889–1891, Hon. Fellow in Assaying, School of Mines. 1891 to date, in partnership with Prof. Ricketts, at above address, in general chemical, metallurgical and mining engineering work, with Ore-Testing Works, at Waverly, New Jersey, for determining treatment of ores, and examination of processes.

BARDWELL, ALONZO FRICK, E.M., ... 1883.
Box 773, Aspen, Col.

BARNARD, EDWARD CHESTER, E.M., ... 1884.
U. S. Geological Survey, Washington, D. C.
Assistant Topographer and at present Topographer in the United States Geological Survey, 1884–1891. Have been engaged in mapping in Virginia, West Virginia, and the mountains of East Kentucky. 1893, Mapping Northern New York.

BARNETT, L. H., M.E., ... 1893.
289 Columbus Ave., New York City.

BARRATT, EDGAR GRANT, C.E., ... 1884.
1022 The Rookery, Chicago, Ill.
1884–1888, Engineer for The Exhaust Ventilator Co. 1888 to date, President and Proprietor of The Exhaust Ventilator Co. 1891 to date, President and General Manager of the Variety Manufacturing Co. Fill the above positions at present and am consulting Ventilating and Heating Engineer.

BARTLETT, FRANK ROOT, C.E., ... 1888.
344 Madison Street, Brooklyn, N. Y.
1888 to date, Assistant Engineer Maintenance of Way on Atlanta and Charlotte Division of Richmond and Danville Railroad. From May, 1892, to date, Supervisor of North-western North Carolina and North Carolina Midlands R. Roads (North Carolina Division of Richmond and Danville Rail Roads).

BARUS, CARL, PH.D. (Associate), ... 1877.
Smithsonian Institute and 1409 30th Street, Washington, D. C.

BAXTER, GEORGE STRONG, A.B., E.M., ... 1868.
17 Broad Street, New York City.
1878–1879, Civil and Mining Engineer. 1880, Cashier N. P. R.R. 1890, Treasurer N. P. R.R.

BEARD, JAMES THOM, E.M., C.E., ... 1877.
Ottumwa, Ia.
1879–80, Assistant Engineer, New York and Brooklyn Bridge. 1880–1882, Assistant Engineer, C. B. and Q. R. R.; 1882–1883, Superintendent Smoky Hollow Mine, Avery, Ia. 1884–1885, Assistant U. S. Dept. Min. Surveyor, Aspen, Colo. 1885–1891, Engineer, Whitebreast Fuel Co., Ottumwa, Ia.; 1891–1892, Manager Miller Creek Land and Lime Co., Aspen, Colo.; 1892–1893, Secretary and Treasurer, Eldon

Coal and Mining Co., Ottumwa, Ia.; 1893 to date, Iowa Mining Exchange, Ottumwa, Iowa. 1892–1894, wrote Beard's *Ventilation of Mines*, published by John Wiley & Sons, New York City.

BEEBE, ALFRED L., PH.B., ... 1880.
Criminal Court Building, Centre Street, New York City and 44 Sanfrid Av., Flushing, L. I.

1880–1887, inclusive, Private Assistant to Prof. Ricketts, School of Mines, New York, in general analytical work, especially Mineral Analyses. Also Assistant in Assaying and Fellow in Chemistry, 1881–1887, inclusive. 1888–1892, Assistant Chemist, New York Health Department. Since September, 1892, Bacteriologist, New York Health Department.

BEHRMAN, GEORGE WILLIAM, C.E., ... 1893.
201 Ross Street, Brooklyn, N. Y.

November, 1893, to January, 1894, Transitman and Draughtsman, with the Raub Locomotive Works and Land Improvement Company.

BELLINGER, HIRAM PAULDING, C.E., ... 1887.
Solvay Process Company, and 1917 W. Genesee St., Syracuse, N. Y.

BEMIS, FREDERICK POMEROY, A.B., E.M., . . . 1885.
109 West 3d St., Davenport Iowa.

BENEDICT, WILLIAM DE LIESSELINE, E.M., . . . 1874.
Welles Bld'g, No. 18 Broadway, Rooms 617 and 618, New York City, and 282 Vanderbilt Avenue, Brooklyn, N. Y.

1878–1880, Assistant Superintendent and Superintendent, Revere Concentrating Co., Utah. 1880–1881, Assistant Superintendent, Germania Smelting & Refining Co., Utah. In 1882, opened an office in New York City as Consulting Mining Engineer and Metallurgist, and have since been engaged in examining and reporting on Mines in the United States, Ontario, Quebec, British Columbia, Mexico and England.

BENJAMIN, MARCUS, PH.B., A.M. (Lafayette 1888) (LifeMbr.) 1878.
PH.D. (Univ. Nashville, 1889), Editor, D. Appleton & Co., 72 5th Ave. and 589 West End Avenue, New York City.

1878–1882, with E. B. Benjamin, dealer in Chemical Apparatus. 1882, Editor *American Pharmacist*. 1883, Editor *Weekly Drug News*, May, 1883, to June, 1885, Chemist, U. S. Laboratory, New York. 1885, Sanitary Engineer, N. Y. Board of Health. 1886–89, Editorial Staff, Appleton's *Cyclopædia of American Biography*. 1890, Editorial Staff, *Engineering and Mining Journal*, chiefly engaged in editing and preparing for the press, George F. Kunz's *Gems and Precious Stones of North America*. 1891–94, Editor of *General Guide to the United States*, *Handbook of Winter Resorts*, and *Handbook of Summer Resorts*, published by D. Appleton & Co. Editorial Staff in charge of Chemistry, Standard Dictionary, 1891, till its completion in 1894. Edited the revised edition *Picturesque America and Art* in 1884, and wrote a booklet entitled, *A Historical Sketch of Madison Square*, during 1894. During 1884–86, Lecturer on Chemistry at New York Women's Medical College and Hospital for Women. At various times on editorial staffs: of *Scientific American*, 1883–89; *Independent Oil Journal*, 1886, and on technical subjects in New York *Daily News*, 1886 to date. New York *Star*, 1890–91 and *Pharmaceutical Record*, 1891, also of Appleton's *Annual Cyclopædia* since 1883. Other work includes translation of Berthelot's lectures on "Explosive Materials" (New York, 1883), authorship of *Druggist's Circular*, Prize Essay on "Disinfectants," authorship of chapters on "Mineral Paints" in *Mineral Resources of the United States*, for years 1884–86, and compilation of a book of Poems, entitled *May Time* (New York, 1889), and authorship of chapter on "Thomas Dongan and the Granting of the New

York Charter," 1682–1688, and "The Development of Science in New York City," in *The Memorial History of the City of New York*, 1892. Contributor to *Scientific American* and *Supplement, The Chatauquan, Harper's Weekly, Popular Science Monthly, The Cosmopolitan*, etc. Organized the Corresponding Chapters of Chemistry of the Agassiz Association in 1892, and has been its President since that date. Life fellow of the London Chemical Society, and of the American Association for the Advancement of Science, Society of Chemical Industry, London, and American Chemical Society. Member International Jury of Awards, World's Fair, Chicago, 1893.

BERRY, WILTON GUERNSEY, PH.B., ... 1886.
Health Department, New Criminal Courts Building, New York City.
1886–1889, Universities of Berlin and Heidelberg and General Chemical Research 1889 to date, Assistant Chemist, New York Health Department.

BERRY, GEORGE, C.E., ... 1888.
78 Morton Street, Brooklyn, N. Y.

BETTS, R. T., C.E., ... 1890.
2789 Atlantic Ave., Brooklyn, N. Y.

BIEN, JOSEPH RUDOLPH, E.M., ... 1887.
140 Sixth Avenue and 321 West Fifty-seventh Street, New York City.
1887–88, Topographer, U. S. Geological Survey, Survey of Geyser Basins, Yellowstone Nat. Park. 1888–90, Practice as Civil and Mining Engineer, firm of Vermeule & Bien, New York City. 1890–91, Practice as Civil and Topographical Engineer alone, New York City. At present, Secretary Julius Bien & Co., Lithographers, Engravers and Geographical Publishers.

BLACK, ADOLPH, C.E., ... 1894.
1434 Lexington Avenue, New York City,

BLAKE, EDWIN MORTIMER, E.M., PH.D. (1893), . . 1890.
Fellow in Mathematics, Columbia College, New York City, and 230 Washington Avenue, Brooklyn, N. Y.

BLOSSOM, FRANCIS, C.E., ... 1891.
Westinghouse, Church, Kerr & Co., 26 Cortland Street, New York City, and 440 Henry St., Brooklyn, N. Y.
1891-92, Engineer with C. W. Hunt Co. 1892, Assistant Engineer Equity Gas Works Construction Company. 1893, as above.

BLYDENBURGH, CHARLES EDWARD, A.B., A.M., E.M., . 1878.
Mining Expert and Prospector, Box 189, Rawlings, Wyoming.

BODELSEN, OSCAR, E.M., ... 1884.
164 W. Sixty-Sixth Street, New York City.

BŒCKLIN, WERNER, JR., C.E., ... 1891.
Assistant Engineer with C. W. Smith, 31 Broadway, and 228 West 38th Street, New York City.
January to May, 1893, ran level on preliminary (150 miles), H. & E. Extension, C. O. & S. W. Railway, in charge of all profiles and estimates under Chief Engineer. 1894, Inspector for Massachusetts Highway Commission on State Highway.

BOGERT, M. T., PH.B, ... 1894.
259 Broadway, Flushing, Queens County, L. I.

BOOK, DWIGHT DANA, C.E., E.E. (1892), ... 1890.
159 Washington Park, Brooklyn, N. Y.

BOORÆM, ROBERT ELMER, M.E. (Life Member), . . 1878.
34 West 11th St., New York City.

1879, Assayer, general work in Leadville, Colorado. 1880–87, Assistant Superintendent, afterward Manager, Evening Star Mining Co., Morning Star Consolidated Mining Co. and others at Leadville, Colorado, Lead-silver Mines. Also in charge Farwell Con. M. Co., Gold Mines at Independence, Colorado. 1887–90, General Manager Blue Bird Mining Co., Ltd., Butte, Montana, Operating 90-Stamp Mill, Dry Crushing, Chloridising, Amalgamating Process. 1891, General Consulting Mining Engineer and Consulting Director in Gold, Silver, and Lead-Mining Companies, of which a Specialty is made. Also Mine Operator and Owner, Silver Mines at Aspen, Colorado.

BOYD, RICHARD CHARLES, PH.B., A.M. (1892), . . 1891.
44 W. 88th St., New York City.

BRADLEY, STEPHEN ROWE, JR., PH.B., ... 1890.
392 Broadway, New York City, and Nyack, N. Y.

July, 1891 to 1894, Secretary and Treasurer Union Electric Co. January, 1894, Secretary and Treasurer The Arlington Manufacturing Co., New York City.

BRASCHI, VICTOR MANUEL, PH.B., E.M., C.E., . . 1881.
Apartado 830, City of Mexico, Mex.

June, 1884, to October, 1884, Inspector of New York Tenement House Commission. October, 1884, to May, 1835, Interpreter and Sec'y to Gov. Chilian Commissioner to Visit and Report on American Mining and Smelting. May, 1885, to October, 1885, Employed by Rend-Rock Powder Co. in Flood Rock Explosion Work. October, 1885, to January, 1889, Assistant Consulting Engineer and in Charge Foreign Business, Rand Drill Co. January, February, March, 1889, Reporting on Mines in Mexico for above Co., and for three years, from April, 1890, to April, 1893, engaged in introducing Rand Rock Drilling Machinery in Mexican mines. In April, 1893, arranged to open a general Mining Machinery and Supply business, in the City of Mexico, in which I am at present engaged.

BRERETON, THOMAS J., A.B., 1879, C.E., . . . 1883.
Engineer Cumberland Valley Railway, Chambersburg, Pa.

1879, Rodman on Location of Redstone Br. P. R. R. 1880 and 1881 (Summers) on New York State Geodetic Survey of Adirondacks. 1883–85, Leveller P. R. R. Clearfield Co. Surveys and Construction. On Corps of Engr. M. of W. P. R. R. 1888–89, Assistant Supervisor, P. R. R. 1890–92, Supervisor Tyrone Div., P. R. R. 1893, Engineer Cumberland Valley Railway.

BREWSTER, HENRY DRAPER (Associate), ... 1883.
Care Brewster & Co., 49th Street and Broadway, New York City.

BRINLEY, JOHN ROWLETT, C.E., ... 1884.
Morristown, N. J.

1884–88, Department of Public Works, New York City. 1888 to date, Civil and Sanitary Engineer.

BRITTON, NATHANIEL LORD, E.M., PH.D., ... 1879.
Columbia College, School of Mines, New York City.

Assistant of Geology, School of Mines, 1879–1887. Instructor in Botany, Columbia College, 1887–1890. Adjunct Professor of Botany, Columbia College, 1890–1891. Assistant, Geological Survey of New Jersey, 1880–1887. Botanist, Geological Survey of New Jersey, 1881–1890. Field Assistant, U. S. Geological Survey, 1882. Professor of Botany, 1891. Specialty—Systematic Botany.

BROSNAN, FRANCIS XAVIER, C.E., ... 1891.
146 W. Seventy-fourth Street, New York City.

BROWN, FRANCIS G., E.M., ... 1867.
Merchant, 15 Whitehall Street and 462 Lexington Avenue, N. Y. City.

BROWNING, JOHN H. BROWER, M.D. (Associate), . . 1883.
Address unknown.

College of Physicians and Surgeons of City of New York, in year 1882. Afterwards Assistant Physician, New York City Insane Asylum, Ward's Island, 1882–83. House Physician and Surgeon to St. Francis Hospital, 1883–85. At date, Member County Medical Society of New York, Member Physicians' Mutual Aid Association, Fellow American Geographical Society, and Assistant to Chair in Surgery, New York Polyclinic, Medical Examiner for Presbyterian Board of Foreign Missions, General Practitioner of Medicine and Surgery.

BRUGMAN, WILLIAM FREDERIC, PH.B., ... 1880.
One Hundred and Forty-fourth Street and Southern Boulevard, New York City, and Los Angeles, Cal.

BRYCE, WILLIAM, JR., PH.B., ... 1884.
40 W. Fifty-fourth Street, New York City.

BUCKLEY, CHARLES RAMSAY, A.B., A.M., E.M., . . 1877.
29 Broadway, New York City.

BULLMAN, CHARLES, PH.B., ... 1883.
Editor *The Safety Valve*, 55 Liberty Street, New York City, and 808 Third Place, Plainfield, N. J.

1883. Tutor in Stoichiometry, Chemist Putnam Company Chemical Works. 1884–1885–86, Venezuela; phosphates, copper. sulphur. 1887, French Guiana; phosphates. 1888, 1889–90, North Carolina, Georgia, Colombia, S. A. (2); gold and platinum. 1891, Sandwich Islands; phosphates. California (2); gold and irrigation. 1892. New Jersey; copper and graphite. 1892–93, Editorial Staff *Engineering and Mining Journal;* also Translator and Editor of *Mining Laws of the Republic of Colombia*, and Author of *Platinum* and *South America* in "The Mineral Industry."

BURDEN, HENRY, 2d., A.B., PH.B., ... 1892.
Cazenovia, N. Y.

BURNS, ABRAHAM LINCOLN, E.M., ... 1887.
3 Worth Street, New York City, and 297 Halsey Street, Brooklyn, N. Y.

Since November, 1887, with Messrs. Jabez Burns & Sons (Millwrights and Machinists, and Manufacturers of Patented Machines for Treating Coffee and Spices). Since July, 1890, in above firm. Professional work has been general shop draughting and machine design, and arranging machines and power transmission in coffee establishments.

BURNS, ELMER Z., E.M., ... 1887.
Niagara Falls, N. Y.

1887–88. Engineer and Chemist for The Pittsburgh and Lake Angeline Iron Co. 1889–90, Assistant Electrician for the United States Electric Light Company. 1890–1891, Assistant Electrician for the Mather Electric Company. 1891–93. City Engineer of Niagara Falls, and Consulting Engineer for the Lewiston and Youngstown R. R. Company, for the North Tonawanda Street Rail Road Company, and for the Niagara Falls and Suspension Bridge Rail Road Company.

BURRITT, WILMOT WOODWARD, PH.B., ... 1884.
Chemist, Englewood, N. J.

BUSH, EDWARD RENSHAW, E.M., ... 1881.
Mining Engineer, with Ricketts & Banks, 104 John Street, N. Y. City.

BUTLER, NATHANIEL, E.M., ... 1880.
51 Cedar Street, Room 7, New York City, and Glen Ridge, Bloomfield, Essex Co., N. J.

1880–1892, U. S. Harbor Improvement and Railroad Engineering. 1882–1894, Barlow's Insurance Surveys as Surveyor, Superintendent and Executive.

BUTLER, WILLIAM CURTIS, M.E., ... 1887.
Everett, Washington, and 175 Hamilton Avenue, Paterson, N. J.

1887–1889, Assayer, El Paso Smelting Co., El Paso, Texas. 1839–1890, Chemist, afterward Assistant Superintendent, Arkansas Valley Smelting Co., Leadville, Colo. 1890, Chemist, now Assistant Manager, Aurora Iron Mining Co., Superior Mining Co., Comet Mining Co., Palone Iron Mining Co., Penokee and Gogebic Development Co. (Operating Colby and Tilden Mines). Also in charge Ironwood Electric Co., Gogebic Electric Co. 1892, Superintendent Monte Cristo Mining Co., Seattle, Washington. 1893, Manager Puget Sound Reduction Co. 1894, President and Treasurer Puget Sound Reduction Co.

BUTLER, WILLARD PARKER, E.M., LL.B. (Life Member), 1878.
Counsellor at Law and Solicitor of Patents, 59 Wall Street, New York City.

C.

CADY, LINUS BERTRAM, E.M., C.E., ... 1877.
327 Fifth Avenue, New York City.

CALMAN, ALBERT, PH.B., PH.D., ... 1882.
332 W. Fifty-sixth Street, New York City.

CANFIELD, AUGUSTUS CASS, E.M., ... 1877.
Address unknown.

CANFIELD, FREDERICK A., A.B., A.M., E.M., . . . 1873.
Mining Engineer, Dover, N. J.

CARSON, JAMES PETIGRU, E.M., ... 1868.
16 Exchange Place, New York City.

CASAMAJOR, GEORGE H., C.E., ... 1892.
138 W. Forty-second Street, New York City, and 372 Greene Avenue, Brooklyn, N. Y.

CASEY, EDWARD PEARCE, C.E., PH.B. (1888), . . 1886.
Architect, 171 Broadway and The Alpine, 55 West Thirty-third Street, New York City.

With McKim, Mead & White, architects, New York City, until January, 1890. Abroad, and Student in L'Ecole National des Beaux Arts, Paris, from February, 1890, until September, 1893. Five mentions in Architecture, and a medal in Modeling. At present Architect, 171 Broadway, New York City.

CAULDWELL, JOHN BRITTON, C.E., ... 1877.
Century Club, 7 West Forty-third Street, New York City.

CHANNING, JOHN PARKE, E.M., ... 1883.
34 Park Place, New York City.

1883, Chemist Hudson River O. and I. Co. 1884, with S. E. Cleaves & Son, Manufacturers of Mining Machinery, Houghton, Mich. 1884-1885, Assistant Mining Engineer Tamarack Mine, Calumet, Mich., Dep. Comm. Mineral Statistics, Michigan. 1885-1886, Superintendent Honduras Land and Navigation Co. 1886-1887, Exploring for iron on the Gogebic Range, and Mining Engineer for Milwaukee L. S. and Western Railway, Superintendent Iron Belt Mine. 1887-1890, Inspector of Mines, Gogebic Co., Mich. 1890-1892, Superintendent East New York Iron Co., Ishpeming, Mich. 1892 to 1893, Superintendent Iron Exploration, C., M. and St. P. Railway.

CHAZAL, PHILIP EDWARD, A.B., E.M., ... 1881.
68 Meeting Street, Charleston, S. C.

1881-1883, Prospecting in Northwest Georgia. 1883-1889, State Chemist of South Carolina. 1889 to present, Partner in Shepard Laboratory, specialties Phosphate and Fertilizer Analysis and examination and reporting on Phosphate lands (in South Carolina and Florida).

CHESTER, ALBERT HUNTINGTON, A.M., E.M., SC.D., PH.D., 1868.
Professor of Chemistry and Mineralogy, Rutgers College, and 35 College Avenue, New Brunswick, N. J.

Professor of Chemistry at Hamilton College from 1870 and Mineralogy from 1878 to 1891. Conducted the Analytical Laboratory there from 1871. Chemist New York State Board of Health, 1882. Examined and reported on mines of iron, gold, silver, lead and zinc, in Michigan, Minnesota, Ontario, Arkansas, Colorado, Utah, Nevada, California, and Nova Scotia. Analytical work has been largely in two lines, viz., for iron-blast furnaces and of paints and varnishes. Field work has been, a great part of it, in the iron mines of Minnesota and the gold mines of Colorado. Now engaged in chemical work for the State Geological Survey of New Jersey.

CHURCH, ELIHU DWIGHT, JR., E.M., ... 1887.
Church & Co., Trenton, Wayne County, Mich.

1887-1888, Fellow Qualitative Analysis, School of Mines. 1888-1889, Assistant Superintendent of Lead Mine and Concentrating Works. 1889-1891, with Church & Co., in charge of experimental plant.

CHURCH, JOHN ADAMS, A.M., E.M., PH.D., . . . 1867.
Corn Exchange Building, 11 William Street, New York City. Cable address, Scotist, N. Y.

CLARK, DIEGO LOMBILLO, C.E., ... 1890.
Cardenas, Cuba.

CLARK, EDMUND (Associate), ... 1892.
Braddock, Pa.

CLARK, EDWIN PERRY, E.M., ... 1880.
Title Guarantee and Trust Co., 26 Court Street, and 464 Second Street, Brooklyn, N. Y.

1880-1883, Engineer and Surveyor for Silver-Cord Combination, and Robert E. Lee Mining companies, Leadville, Colo. 1883-1884, Medical student. 1884 to date, Assistant Superintendent and afterwards Superintendent Title Guarantee and Trust Company, 55 Liberty Street, New York, and 26 Court Street, Brooklyn. In charge of construction and maintenance of locality-indexes of Real Estate Records of New York, Kings and Westchester counties, N. Y.

CLARK, FRANKLIN SINCLAIR, E.M., PH.D., . . . 1885.
Carolina Oil and Creosote Co., Wilmington, N. C., and 527 Madison Avenue, New York City.

1885–1887, Chemist to Fernoline Chemical Co., Charleston, S. C. 1887 to date, Proprietor of Southern Chemical Works and consulting chemist for the Carolina Oil and Creosote Co., Wilmington, N. C. Specialty, Distillation of Wood and refining products and creosoting wood.

CLARK, WILLIAM C., M.E., ... 1892.
Cranford, N. J.

CLARK, GEORGE HALLETT, C.E., ... 1893.
Lex. Ave. and P. Ferry R.R. Co., 621 Broadway, Room 840, and 59 E. Sixty-seventh Street, New York City.

1893–94, Transitman Metropolitan Traction Co., Lexington Ave. Cable Construction. Assistant Engineer in charge construction Lexington Avenue Cable Road.

COKEFAIR, FRANCIS A., C E., ... 1894.
66 Broadway, New York City, and 119 Crescent Ave., Plainfield, N. J.

COLBY, ALBERT LADD, PH.B., ... 1881.
The Bethlehem Iron Co., South Bethlehem, Pa.

1881–1883, Assistant to Prof. C. F. Chandler on New York State Board of Health Bureau of Chemical Analysts. 1883–1886, Instructor in Quantitative analysis and Chemical Philosophy in the Lehigh University, South Bethlehem, Pa. 1886–92, Head Chemist of the Bethlehem Iron Co. 1893 to date, Metallurgical Engineer same Company, South Bethlehem, Pa. Specialty, Metallurgy of Iron and Steel.

COLBY, CHARLES EDWARDS, E.M., C.E., ... 1877.
Adj. Professor Organic Chemistry, Columbia College School of Mines, New York City.

COLE, HAROLD MORRIS, E.M., C.E., ... 1887.
Care United S. and R. Co., East Helena, and 1045 N. Warren Street, Helena, Montana.

COLTON, CHARLES ADAMS, E.M., ... 1873.
21 W. Park Street, and 57 Broad Street, Newark, N. J.

1873–1882, Assistant in Mineralogy, School of Mines, Columbia College, New York. 1882–1884, Professor of Chemistry and Mineralogy, Rose Polytechnic Institute, Terre Haute, Indiana. 1884 to date, Director and Instructor in Chemistry and Physics, Newark Technical School.

CONANT, HENRY DUNNING, E M., ... 1886.
Care Messrs. Gaminara & Leeder, Tumaco, Republic Colombia, S. A.

1886–1888, Assistant Engineer Tamarack and Osceola Mines, Lake Superior, and H. and C. R.R. 1888–1889, Assistant Engineer on Preliminary of Northern Michigan Railroad. 1889, Assistant in Chief Engineer's Office, Buffalo and Geneva Railway. 1889-91, Assistant and Resident Engineer Norfolk and Western Railroad, in charge of Preliminary Location and Construction. 1891, Engineer Coeburn Land and Improvement Co. 1893, Assistant Engineer N. Y., N. H. & H. Ry. 1894, Assistant Engineer Plaza de Oro Mining Co., Ecuador, S. A.

CONGDON, ERNEST ARNOLD, PH.B., F.C.S., . . . 1887.
Professor of Chemistry, Drexel Institute Arts, Science and Industry, and 1336 Spruce Street, Philadelphia, Pa., or care H. M. Congdon, 18 Broadway, New York City.

1887–1889, Chemist to Champlain Fibre Co., Willsborough, New York. 1889, Studied at the University of Berlin, Summer Semester. 1889 to date, Instructor in Qualitative Analysis and Assaying at the Lehigh University. 1891, Professor of Chemistry in the Drexel Institute of Arts, Sciences and Industries, Philadelphia, Pa.

CONNELL, HEWLETT RAISTON, C. E., ... 1890.
140 Pierrepont Street, Brooklyn, N. Y.

COOPER, WILLIAM HAMILTON, PH.B. (Life Member), . 1882.
Address unknown.

CORCORAN, JOHN THOMAS, E.M., S.E., ... 1884.
131 Smith Street, Brooklyn, N. Y.

CORNELL, GEORGE BIRDSALL, E.M., C.E., . . . 1877.
29 Broadway and 46 West Forty-eighth Street, New York City.

Assistant Engineer Manhattan Elevated Railway. Engineer for Contractors for structure Manhattan Elev. Ry. Assistant Engineer Brooklyn Elev. Ry. Assistant Engineer New York, Chicago and St. Louis R. R. Principal Assist. Engineer Rochester and Pittsburgh Ry. Inspector and Engineer Bridge Dept. N. Y., West Shore and Buffalo Ry. Principal Assist. Engineer Brooklyn Elevated Ry. Chief Engr. Brooklyn Elev. Ry. Chief Engr. Union Elevated Ry. of Brooklyn. Chief Eng. Chicago and South-side Elev. Ry. Chief Engr. J. B. & J. M. Cornell Iron Works. At present Chief Engineer East River Bridge Company.

CORNWALL, HENRY BEDINGER, A.B., A.M., E.M., PH.D., 1867.
Professor Analytical Chemistry and Mineralogy, College of New Jersey, and 51 Nassau St., Princeton, N. J.

CORNWALL, HARRY CLAY, E.M., ... 1879.
Commonwealth Insurance Co., Nassau Street, New York City.

COX, JENNINGS STOCKTON, JR., MET. ENG., . . . 1887.
76 W. Sixty-eighth St., N. Y. City.

1887, Government Survey for Canal between Harlem and Hudson River. 1888–1889, Homestead Steel Works, Draughtsman and afterward Assistant Master Mechanic. 1890, Inspected construction of Steamer "Sezurania" and "Vigilancia" for the U. S. and B. M. S. S. Co., at Roach's Shipyard, Chester, Pa. 1891, Reporter for same Company on Engineering matters along the Brazil coast. 1892, with same company in New York. 1892, Assist't Superintendent Aurora Iron-Mining Company, Ironwood, Michigan. 1893, Assist. Supt. Monte Cristo Mining Co., Pride of the Mountain Mining Co., Rainy Mining Co., and United Concentration Company.

CRAMER, STUART W., E.M. (Associate), ... 1889.
Charlotte, N. C.

Graduate of United States Naval Academy; resigned from the United States Navy September, 1888. Graduate student at School of Mines, 1888–1889. Assayer in charge of the United States Assay Office, Charlotte, N. C., 1889–93. Special agent for collection of statistics on gold and silver for the Southern States, 1890. March 10, 1893, to present time, Engineer and Chemist for the D. A. Tompkins Company, General Engineers and Contractors, of Charlotte, N. C. Special correspondent of *Engineering and Mining Journal*. Specialty: Westinghouse system of electric lighting and transmission of power.

CROCKER, FRANCIS BACON, E.M., ... 1882.
Professor Electrical Engineering, Columbia College School of Mines, and 26 W. 22d Street, New York City.

1882–1886, Electrical Engineer and Inventor. 1886–1887, Vice-President and Electrician of "C. and C." Electric Motor Co. 1887–1889, Vice-President and Electrician Crocker-Wheeler Electric Motor Co. 1889–92, Instructor in Electrical Engineering, School of Mines, Columbia College. 1892, Adj. Professor. 1893, Professor.

CUSHMAN, ALEXANDER RAMSAY, PH.B., PH.D, . . 1878.
Assistant Analytical Chemistry, Columbia College School of Mines, and 128 E. Sixteenth Street, New York City.

1878–1880, Post Graduate study at the School of Mines, for degree of Ph.D. 1880–1882, in Colorado, visiting mines and smelters. 1882–1890, Engaged in pursuing chemical studies and lecturing on geology. 1890 to date, Assistant Instructor in Qualitative Laboratory at the School of Mines, Columbia College.

D.

DARWIN, HARRY GILBERT, C.E., ... 1887.
Room 23, 160 Broadway, New York City, and Glen Ridge, N. J.

June, 1887, to October, 1887, Rodman and Leveller on Railroad field work in New York State. October, 1887, to May, 1888, Draughtsman Strong Locomotive Co., New York City. August, 1888, to date, Assistant Engineer and Acting Superintendent Safety Car Heating and Lighting Co., New York City. Erection of special gas works, and equipment of railroad cars, etc. P. Asst. Eng. S. C. H. L. Co.

DAVIS, CHARLES HENRY, C.E., ... 1887.
120 Broadway, New York City, 308 Walnut Street, Philadelphia, and 576 Lexington Avenue, New York City.

Expert course and Thomson-Houston Electric Co., Lynn, Mass., summer 1887. Agent, Lawyer Mann Electric Co., winter 1887–88. Supt. selling and construction New York office S. M. Elec. Co., summer and winter 1888. Agent Westinghouse Electric Company, winter 1889. Consulting and Supervising Electrical Engineer from May, 1889, to date.

DAVIS, JOHN WOODBRIDGE, C.E., PH.D., ... 1878.
Principal Woodbridge School, 417 Madison Avenue, New York City.

DEGHUÉE, JOSEPH ALBERT, PH.B., A.M. (1892), PH.D. (1893), ... 1890.
College Phys. and Surg., New York City, and 247 Harrison St., Brooklyn, N. Y.

Assistant Demonstrator in Physics and Chemistry, College of Physics and Surgery.

DELAFIELD, AUGUSTUS FLOYD, PH.D. (Associate), . . 1869.
University Club, New York City.

DE LUZE, LOUIS PHILIPPE, C.E., ... 1879.
DeLuze & Emmett, Engineers and Surveyors, New Rochelle, N. Y.

DENTON, FREDERICK WARNER, C.E., ... 1884.
Minnesota Iron Co., Soudan, St. Louis Co., Minn.

1889–90, Fellow in Engineering, School of Mines. 1890–94, Professor of Mining and Civil Engineering, Michigan Mining School, and in general practice of engineering. 1894 to date, Mining Engineer Minnesota Iron Co. Secretary of the Lake Superior Mining Institute since its organization in 1893.

DEVEREUX, WALTER BOURCHIER, A.B., A.M., E.M., . 1878.
Sherman Square Hotel, New York City.

DODGE, FRANK DESPARD, PH.B., PH.D., . . . 1888.
Dodge & Olcott, 137 Water St. and 111 Montague St. Brooklyn, N. Y.

From October, 1891, to date, Chemist, with Dodge & Olcott, manufacturers of essential oils, etc. 1888–90, Fellow in Chemistry, Assistant in Organic Laboratory School of Mines. 1890–91 (studying in Germany).

DODSWORTH, WALTER ALBERT, PH.B., ... 1888.
19 Beaver Street, New York City, and 253 Henry Street, Brooklyn, N. Y.
With Journal of Commerce and Commercial Bulletin.

DOLAN, CHARLES FRANCIS, C.E., ... 1892.
111 East 129th Street, New York City.
1892-93, United States Inspector of Dredging Operations, Harlem Ship Canal and Newtown Creek. 1893 to date, with Department of Street Improvements, New York City. 1894, With U. S. Engineers on New York Harbor Improvements.

DONNELL, HARRY ELLINGWOOD, PH.B., ... 1887.
Address unknown.

DOUGLAS, JOHN SHEAFE, C.E., ... 1890.
72½ Irving Place, New York City.
1890, Course Electrical Engineering, Columbia College. 1891, Crocker-Wheeler Electric Motor Company, and now Assistant Engineer Western Electric Company in Lighting Department. 1893, Superintendent of Union Elect. Co.'s Exhibit at World's Columbian Exposition, Chicago.

DOUGLASS, EDWARD MOREHOUSE, C.E., ... 1881.
Topographer U. S. Geol. Survey, and Takoma Park, Washington, D. C.

DOW, ALLAN WADE, PH.B. (Life Member), . . . 1888.
Office of the Engineer Commission, District of Columbia, and The Eckington, Third and T Streets, N. E., Washington, D. C.
1888-89, Honorary Fellow Quant. Laboratory, School of Mines. 1889, Chemist at Tilly Foster Mine, New York. 1889-91, Assistant Chemist of The Barber Asphalt Paving Co. 1894, District Chemist, Inspector Asphalt Cement and Building Stone, District of Columbia.

DOWNES, STANCLIFF BAZEN, C.E., ... 1882.
1071 Madison Avenue, New York City.
December, 1882, to April, 1885, Assistant, Office Topographical Engineering Department Public Parks, New York City. April, 1885, to January, 1891, Assistant Engineering Department Public Parks. April, 1886, elected Junior Member American Society Civil Engineers. January, 1891, to date, Civil Engineer, Fordham, New York City, opposite Harlem Railroad station.

DOWNS, WILLIAM FLETCHER, E.M., ... 1882.
Joseph Dixon Crucible Co., and 75 Fairview Avenue, Jersey City, N. J.
With the Joseph Dixon Crucible Co. since graduation. From June, 1882, to September, 1882, at experimental work. From September, 1882, to October, 1884, in charge of lubricating department. From October, 1884, to present time Superintendent of crucible and other departments.

DRESSER, DANIEL LEROY, C.E., ... 1889.
Dresser & Goodridge, 55-57 White St., New York City, and Oyster Bay, L. I., N. Y.

DRUMMOND, ISAAC WYMAN, E.M., PH.D., . . . 1878.
F. W. DeVoe & Co., William and Fulton Streets, New York City.

DUFOURCQ, EDWARD LEONCE, M.E., ... 1892.
San Miguel de Mesquital, Catalina, Durango, Mexico, and 846 Lexington Avenue, New York City.
1892-93, Assistant Superintendent Costa Rica Pacific Gold Mining Company, Punta

Arenas, Costa Rica. Summer of 1893, Assistant in Mining, Columbia College and Transitman for J. F. Carey & Co., Brooklyn. November, 1893, Assistant Engineer, Mazapil Copper Company, Concepcion de Oro, Zacatecas, Mexico, and Assistant Engineer Cralinila and Zacatecas R.R. Fall of 1894, Engineer of International Mining Co., San Miguel de Mesquital, Mexico.

DUNHAM, EDWARD KELLOGG, PH.B., ... 1881.

338 East Twenty-sixth Street, and 110 W. 57th St., New York City.

Professor of Pathology, Bacteriology and Hygiene in the Bellevue Hospital Medical College, New York City.

DUSENBERRY, WALTER LORTON, E.M., ... 1884.

220 Tenth Street, S. Brooklyn, N. Y.

1884–87, miscellaneous. U. S. Coast Survey. Mining in Mexico and the west. Survey of New Parks, Westchester County, etc. 1887–89, Inspector of Masonry and Transitman on New Croton Aqueduct. 1889–91, in charge of party and Assistant Engineer of Construction Department of Public Parks, New York City.

DUTCHER, BASIL H., PH.B., ... 1892.

525 Manhattan Avenue, New York City.

Summer of 1890, on Reconnaisance Survey in Idaho and Nevada, Biological Survey, U. S. Department of Agriculture. Summer of 1891, on Death Valley Survey, California, U. S. Department of Agriculture. Summer of 1892, Biological Survey, U. S. Department of Agriculture, in Kansas, Oklahoma, Texas, New Mexico. Winters, 1892–93 and 1893–94, Student, College Physicians and Surgeons, Columbia College.

DWIGHT, ARTHUR SMITH, E.M., ... 1885.

Superintendent Colorado Smelting Co., Pueblo, Colorado.

1885, Assistant Assayer at works of The Colorado Smelting Company, Pueblo, Colorado. 1885 to 1888, Assistant Chemist and Chemist, except autumn of 1886, when examining and reporting on lead deposits of Cœur d'Alene region, Idaho Territory, and spring of 1889, when acting as Assistant Supt. Madonna Mine, Monarch, Colo. 1888–90, Metallurgist, and 1890 to date, General Supt. of the Colorado Smelting Co.

E.

EASTON, LANGDON CHEVES, C.E., ... 1884.

Port Harford, San Luis Obispo Co., Cal., and 344 South Grand Avenue, Los Angeles, Cal.

1885–88, Engineer Corps, Aqueduct Commission, New York City. 1889, City Surveyor's Corps, Los Angeles, Cal. 1889 and 1891, in charge of harbor improvements, Port Harford, Cal., under direction of U. S. Corps of Engineers.

EASTWICK, GEORGE SPENCER, C.E., ... 1879.

Manager American Sugar Refinery Co., 24 North Peters St., New Orleans, La., and 1425 Broadway, New York City.

EASTWICK, EDWARD PEERS, JR., PH.B., S.E., C.E. (1892), 1889.

Care of American Sugar Refining Company, New Orleans, La.

EBERHARDT WILLIAM G., M.E., ... 1891.

Concepcion del Oro, Zacatecas, Mexico, and 450 W. Twenty-second St., New York City.

1891–93, General Engineering and Draughting. March, 1893, to May, 1894, Assistant Superintendent and Assayer Powhatan Lead and Mining Co., Va. At present Assayer and Surveyor Mazapil Copper Co., Concepcion del Oro, Zacatecas, Mexico.

EDDIE, EDWARD CRITTENDEN, E.M., ... 1885.
Colorado Smelting Co., Box 8, Pueblo, Colo.

EDWARDS, RICHARD MASON, E.M., ... 1886.
Red Jacket and Houghton, Mich.
1886–87, general assay office at Houghton, Mich. 1888–89, Professor of Mining, Michigan Mining School, Houghton. 1890 to date, Mining Engineer for Tamarack, Tamarack, Jr., Osceola and Kearsarge Mining Cos., L. S., Mich.

EILERS, KARL EMRICH, E.M., ... 1889.
Care of Colorado Smelting Co., Pueblo, Col., and 751 St. Mark's Avenue, Brooklyn, N. Y.
1889–91, student and travelling in Europe.

ELLIOTT, ARTHUR HENRY, PH.B., PH.D., . . . 1881.
4 Irving Place, N. Y. City, and Peekskill, N. Y.
Professor Chemistry and Physics, New York College of Pharmacy. Chemist to Consolidated Gas Co. Editor Anthony's *Photographic Bulletin*. Author A. H. Elliott's Qualitative Chemical Analysis.

ELLIOTT, WILLIAM, PH.B., ... 1880.
56 Wall St., New York City.

ENGEL, LOUIS GEORGE, E.M., ... 1880.
Brooklyn Sugar Refinery, American Sugar Refining Co., and 238 Clermont Avenue, Brooklyn, N. Y.
Three years, Tilly Foster Iron Mine (E. M.). Ten years, Brooklyn Sugar Refinery.

ENGELHARDT, EUGENE NICHOLAS, E.M., . . . 1885.
Selby, Contra Costa Co., Cal.
1886, Assayer, Chemist and Assistant Superintendent Pueblo Smelting and Refining Co. 1887 and 1888, Superintendent of the same company. 1889, Assistant Superintendent Anaconda Smelting Co. From 1890 and to present time, Assistant Superintendent Selby Smelting and Lead Co.

F.

FAHYS, GEORGE ERNEST, C.E., ... 1884.
38 Maiden Lane, New York City, and 285 DeKalb Avenue, Brooklyn, N. Y.
Treasurer, Prentiss Calendar Time Co.

FALK, DAVID BEAUREGARD, C.E., ... 1882.
Savannah, Ga.

FEARN, PERCY LE ROY, E.M., ... 1889.
1326 Monadnock Bldg., Chicago, Ill.
1889–90, Assayer and Surveyor, Trinidad Mine, Costa Rica. 1890–92, Superintendent, Trinidad Mine, Costa Rica. 1892–93, Consulting Mining Engineer Illinois Fluor Spar and Lead Co.

FERGUSON, WILLIAM CUSHMAN AUGUSTINE, PH.B., . 1887
Nichols Chemical Co., Laurel Hill Chemical Works, Laurel Hill, N. Y., and 520 Nostrand Ave., Brooklyn, N. Y.
Chief Chemist, Nichols Chemical Co., Laurel Hill, N. Y.

FERRER, CARLOS FERRER, C.E., ... 1883.
39 Broad Street, New York City.

After graduation, for a few weeks on work at the School of Mines. Then under Mr. W. E. Worthen, C.E., on some work for the Water Commissioners of the State of New Jersey. From March, 1884, to January, 1887, on the Engineering Corps of the Aqueduct Commissioners, New York City, as Assistant to Engineer of Construction; Leveler in charge of field work on Section "A"; reduced to Rodman in charge of same; promoted to Assistant Engineer: resigned in January, 1887, and have since been engaged in business for my own account at above address.

FERRIS, JUNIUS COLTON, E.M., ... 1883.
Carthage, Ill.

FEUCHTWANGER, HENRY, PH.B., ... 1882.
Room 19, 99 Franklin Street, New York City.

FIALLOS, ENRIQUE CONSTANTINO, C.E., ... 1883.
No. 27, Calle 10a, Tegucigalpa, Honduras, C. A., and care Ernest Schernikow, P. O. Box 3540, N. Y. City.

General practice in Engineering. Professor of Mathematics and Mineralogy in the University of Tegucigalpa. The most extensive practice has been as Government Surveyor of Lands and Mines.

FISHER, WILLARD, E.M., ... 1888.
Agent Illinois Zinc Co., 115 Broadway, and 361 W. Fifty-sixth St., New York City.

Draughtsman to Parsons, C.E., New York City. Assistant to Superintendent Segovia Gold Mining Co., Nicaragua. Clerk, Office of Rich Hill Coal Mining Co., Rich Hill, Mo. Engineer and Mine Surveyor, Rich Hill Coal Mining Co., Rich Hill, Mo. Prospecting for coal, Southwest Missouri, along the line of Wichilaw & Western in the interest of the Missouri Pacific Railroad. Southern Sales Agent, Coal Cos. on the lines of Missouri Pacific Railway. President Tyler S. E. Railway of Texas.

FLOYD, FREDERICK WILLIAM, C.E., E.M., ... 1877.
539 W. Twentieth St. and 175 W. Eighty-seventh St., N. Y. City.

1877–78, Honorary Assistant in Metallurgy, School of Mines. 1878–81, U. S. Geographical Surveys, West of 100th Meridian. 1881–82, Preliminary Surveys, New Croton Aqueduct and Dam, New York. 1882, Reporting on Mines in Colorado. 1883 to date, Firm of James R. Floyd & Sons, Iron Works. Specialty, Gas Engineering and Gas Works Construction.

FOLGER, EDWARD P., ... 1894.
80 Quincey Street, Brooklyn N. Y.

FOSTER, REGINALD GUY, C.E., ... 1893.
16 E. Thirty-first Street, New York City.

FOWLER, ALBERT CASIMIR, C.E., ... 1889.
Cienfuegos, Cuba.

FOWLER, SAMUEL STEWART, A.B., E.M., ... 1884.
Golden, British Columbia, Canada, and Room 201, 34 Clark Street, Chicago, Ill.

1885, Civil Engineering Work, New York. 1886, Assistant Superintendent, Iron Hill Mining and Milling Co., Black Hills, South Dakota. 1887, Assistant Superintendent Galena Reduction Co., Black Hills, South Dakota. 1888, Superintendent, International Smelting Works, Texas. Engineer and Assayer, Bunker Hill and Sul-

livan Mg. and Conc. Co., Idaho. 1889, Reporting sundry properties. 1890 to date, Superintendent Golden Mining and Smelting Co., Golden, B. C., Canada. Deputy Commissioner World's Columbian Exposition, 1893.

FOYÉ, ANDREW ERNEST, C.E., ... 1890.

Instructor in Civil Engineering, School of Mines, Columbia College, and 163 West Seventy-ninth Street, New York City.

1890–92, Engineer's office, M. W. P. R. R. 1892–94, Tutor in Civil Engineering, School of Mines. 1894, Instructor in same.

FRANK, JEROME WILLIAM, PH.B., ... 1888.

29 Broadway, New York City.

FREEDMAN, WILLIAM HORATIO, C.E., ... 1889.

Freedman, Rennard & Co., 136 Liberty Street, and 120 W. One Hundred and Twenty-fifth Street, New York City.

Post-graduate in Elect. Engineering, 1889–91. John Tyndall Fellow, 1891–92. Tutor in Elect. Engineering, since 1892. Additional degree of E. E. in June, 1891.

FRIEDMAN, SAMUEL, C.E., ... 1892.

Tuscaloosa, Ala.

FURMAN, HOWARD VAN FLEET, E.M., ... 1881.

U. S. Mint, Denver, Col.

1882–88, Assayer and Chemist and Foreman, Germania Lead Works, Utah. Chemist, Globe Smelting and Refining Co., Denver. Assistant Superintendent, Billings Smelter, Socorro, New Mexico. Superintendent, Bailey Smelter, Denver, Colo. 1888–91, some experience as Consulting Engineer and Metallurgist. 1894, Chief Assayer U. S. Mint, Denver, Colo.

G.

GARLICHS, HERMAN, E.M., ... 1880.

Velardena, Estado de Durango, via Eagle Pass, Mexico.

1880–83, Surveying and Reporting on Mines in Colorado. 1883–87, Assistant Superintendent, Aurora S. & R. Co., Aurora, Ill. 1887 to 1894, Superintendent Refining Department, Omaha and Grant S. and R. Co. Specialty, Silver and Lead Smelting and Refining. 1894, Metallurgist, Velardena Mining Co.

GIFFORD, STANLEY DEVOL, E.M., ... 1889.

Butte City, Montana, and Tuckahoe, N. Y.

Vice-President, Montana Ore Purchasing Co.

GOING, CHARLES BUXTON, PH.B., ... 1882.

President Cincinnati Desiccating Co., Cincinnati, and Glendale, Ohio.

Trustee and Secretary and Treasurer, Glendale Water Works, 1892–95.

GOLDSCHMIDT, SAMUEL ANTHONY, A.B., A.M., E.M., PH.D. (Life Member), ... 1871.

Treasurer Columbia Chemical Works, 43 Sedgwick St., Brooklyn, N. Y., and New York City.

Assistant Ohio Geological Survey, 1871. Chemist and Assistant Inspector of Fertilizers, Savannah, Ga., during winters of 1871–75. During summers, Assistant to Dr. Chandler, Inspector New York Board of Health, 1873–75. Reporting on Guano Islands, South Pacific, 1876. General Consulting Practice, 1876–80. Inspector Offensive Trades, New York Board of Health, 1879–88. Treasurer and Manager Columbia Chemical Works, 1880 to date. Specialty, Ammonia Manufacture.

GOOD, GEORGE MCCLELLAND HOUTZ, E.M., . . . 1886.
Mining Engineer, Osceola Mills, Clearfield Co., Pa.
1892, Mining Engineer to The United Collieries Company. 1893, Assistant Gen'l Manager of the same.

GOODWIN, EDWARD, E.M., ... 1891.
Napa City, Napa County, Cal., and Governor's Island, N. Y.

GORDON, JOHN, JR., E.M., ... 1871.
G. O. Gordon, 69 Wall St., N. Y. City.
Merchant. Edward Johnston & Co., 62 Sas Pedro, Rio de Janeiro, Brazil.

GOSLING, EDGAR BONAPARTE, E.M., C.E., PH.D., . . 1884.
Windsor Hotel, New York City.
Tutor in Mathematics, Columbia College from 1884 to 1885. Draughtsman and afterwards Assistant Engineer in Department of Docks, New York City, 1886-88. In Manufacturing Business in Paris, France, 1888-89. Tutoring in Mathematics and Engineering Branches in New York, and Superintending building of houses, introducing Culm-burning Furnace in U S., 1889-91. In charge of erection of buildings in artificial stone (Beton Coignet), for the Suez Canal Company, Egypt.

GRAFF, CHARLES EVERETT, E.M., ... 1885.
50 Highland Avenue, Jersey City, N. J.
1885-87, Assistant Engineer, Central Entre Riano Railroad, Argentine Republic, S. A. 1887-88, Engineer, Arizona Union Mining Co., Prescott, Arizona. 1888-90, Manufacturing Work, Binding Twine and Reapers. 1890-91, Engineer, Eagle Oil Co.

GRANGER, A. D., C.E., ... 1892.
198 Hooper Street, Brooklyn, N. Y.

GRATACAP, LOUIS POPE, PH.B., ... 1876.
Curator American Museum Natural History, Seventy-seventh Street and Eighth Avenue, New York City, and West New Brighton (Richmond County), Staten Island, N. Y.

GREENLEAF, JAMES LEAL, C.E., ... 1880.
Consulting Engineer, No. 1 Broadway, New York City, and Llewellyn Park, West Orange, N. J.
Special Agent for Tenth Census for Water-power from 1880 to 1882. Since instructing in engineering, civil and sanitary, in School of Mines, Columbia College. 1891, Adjunct Professor Civil Engineering, Columbia College.

GREEN, DAVID JOY, C.E, ... 1894.
300 Oakland Avenue, Brooklyn, N. Y.

GRISWOLD, WILLIAM TUDOR, C.E., ... 1881.
U. S. Geological Survey, Washington, D. C., and Boise City, Idaho.

GROSS, LOUIS NATHAN, B.S., E.M., ... 1884.
Merchant and 38 East Fifty-eighth Street, New York City.

GUDEMAN, EDWARD, PH.B., PH.D., ... 1887.
Peoria Grape Sugar Co., Peoria, Ill., and P. O. Box 3001, N. Y. City.
Student at the Universities of Berlin and Göttingen, 1887-89. Private Assistant with Dr. C. F. Chandler, and Honorary Assistant at the School of Mines. 1889 and 1890, Professor of Chemistry in charge of the Department of Chemistry, Dyeing and Pottery at the Pennsylvania Museum and School of Industrial Art, Philadel-

phia, Pa. 1890-92, Chemist with the American Glucose Company at Buffalo, N. Y., and Peoria, Ill. 1892-93, Chemist in charge of Peoria Grape Sugar Company, at Peoria, Ill. 1893 to date, Chemical Superintendent of the same.

GUDEWILL, CHARLES EDWARD, C.E., ... 1890.

P. O. Box 874, Montreal, Canada, and 2 W. 47th St., New York City.

1890-91, Assistant in Engineering Department, School of Mines, under Prof. Trowbridge. 1891 to date, Assistant Engineer Dominion Construction Co., Montreal, Canada.

GUITERMAN, EDWARD WOLF, PH.B., ... 1889.

Passaic Print Works, Passaic, N. J., and 335 West Fifty-eighth Street, New York City.

1890 to date, Chemist above works.

H.

HAASIS, DUNBAR FERDINAND, E.M., ... 1883.

U. S. S. "Gedney," Box 173, and 83 Rector St., Perth Amboy, N. J.

1883-84, Inspector of bridge work, Stony Point, New York. 1885-88, Assayer and Chemist, afterwards General Manager Parral Mining and Milling Co. (silver), Mexico. 1889, with Corps of Engineers, U. S. A., on New York Harbor Improvements. 1890 to date, Engineer Marion Phosphate Co., Florida, and Engineer Hamburg Phosphate Co., Florida. Surveying, prospecting and reporting on phosphate deposits. 1892-93, with U. S. Engineers in charge construction Concrete Fortifications. In charge of Harbor Improvements. Assistant Engineer of Dominion Construction Company for pipe laying and Reservoir engineering.

HAFFEN, LOUIS FRANCIS, A.M., C.E., ... 1879.

Commissioner Street Improvements, One-Hundred and Forty-first St. and Third Ave. and 647 Cortlandt Ave., 23d Ward, N. Y. City.

HALE, ALBERT WARD, A.B., A.M., E.M., ... 1867.

Department Public Works, East Twenty-fourth Street, and 81 Clinton Place, New York City.

HALL, ROBERT WILLIAM, E.M., ... 1876.

Chemical Building, University of New York, University Heights, 24th Ward, New York City.

From 1879 to 1888, Chemist to the American Gas Fuel and Light Company and to some associated companies. Since the autumn of 1888, Acting Assistant Professor of General Chemistry in the University of the City of New York. Since the autumn of 1890, also Acting Professor of Analytical Chemistry in the same institution. 1891, Professor of Analytical Chemistry, same institution.

HALLOCK, ALBERT PETER, PH.B., PH.D., ... 1880

440 First Avenue and 434 Lenox Avenue, New York City.

June, 1880, to October, 1880, with Dr. P. de P. Ricketts. October, 1880, to November, 1887, Chemist Consolidated Gas Co. November, 1887, to January, 1889, in the shell lime business. January, 1889, to date, Chemist to Carl H. Schultz, Mineral Water Factory. Specialty, Gas and Mineral Water Chemistry.

HAMILTON, FRANK C., E.M., ... 1894.

Assistant Assayer Colorado Smelting Co., Pueblo, Colo.

HANKINSON, ALBERT WORTHINGTON, C.E., . . . 1893.

114 West Forty-fifth Street, New York City.

HANNA, GEORGE BYRON, A.B., E.M., ... 1868.
Charlotte, N. C.
Chemist and Assistant Geologist North Carolina Geological Survey. Melter and Assistant Assayer U. S. Assay Office, Charlotte, N. C. Also Consulting Mining Engineer and Chemist, etc.

HANSON, R. C., ... 1894.
79 Manhattan Ave., New York City.

HARDING, GEORGE EDWARD (Associate), ... 1867.
Architect, 253 Broadway, New York City.
Fellow American Institute Architects and Member American Society Civil Engineers.

HARRINGTON, THOMAS HENRY, C.E., ... 1889.
West Chester, West Chester County, N. Y.
July, 1889, to March, 1893, Inspector Clerk and General Superintendent on U. S. Works, Flood Rock, Hell Gate, East River, N. Y. April, 1893, in charge of Exhibit of River and Harbor Improvements from New York City and Hudson River, at World's Columbian Exposition, Chicago.

HARRIS, EDWIN. A., PH.B., ... 1889.
Secretary and Treasurer, Globe Steam Heating Co., 412 N. Eleventh Street, St. Louis, Mo.
1889-90, Chemist of the Camden Consolidated Oil Company. 1890 to date, Chemist Camden Consolidated Oil Company and agent for oil, mineral and timber lands in West Virginia and Ohio. Chemist to the Phosphorus Works of J. J. Allen's Sons, 2 Chestnut St., Philadelphia, 1892-93. April, 1893, to date, Secretary and Treasurer Globe Steam Heating Company.

HARTE, CHARLES R., C.E., ... 1893.
Box 136, Milford, Conn.

HASKELL, H. G., ... 1893.
915 Delaware Avenue, Wilmington, Del.

HAAS, EDWARD F., C.E., ... 1894.
Stockton, Cal.

HATHAWAY, NATHANIEL, PH.B., ... 1879.
Swain Free School, and 43 Elm Street, New Bedford, Mass.
1879-80, Booth and Edgar Sugar Refinery. 1880-83, Private Assistant to Dr. E. Waller, New York. 1883-91, Teacher of Chemistry and Physics Swain Free School, New Bedford, Mass., and general analytical work.

HAWLEY, JOHN FRANCIS, C.E., ... 1891.
Apartado 172, Guatemala, C. A.

HÉBERT, OCTAVE BRITTON, C.E., ... 1888.
61 Park Place and 72 W. 69th Street, New York City.

HEINSHEIMER, ALFRED MAURICE, C.E., ... 1887.
Kuhn, Loeb & Co., 27-29 Pine Street, and 71 West Seventieth Street, New York City.

HENDRICKS, HENRY HARMON, PH.B. (Life Member), . 1880.
Hendricks Bros., 49 Cliff Street, New York City.

HERCKENRATH, WALTER AUGUSTUS, A.M., C.E., . . 1892.
Address unknown.

1892-93, Erie City Iron Works and with City Engineer on pavements and sewers; Wilmington, Vt., on Railway and General Engineering; Inspector U. S. Dredging Operations, Gowanus Bay. 1893, Temporarily employed in the Mathematical Department of the University of Ottawa.

HEWLETT, JAMES MONROE, PH.B., ... 1890.
Lord & Hewlett, Architects, 123 E. Twenty-third Street, New York City, and 77 Columbia Heights, Brooklyn, N. Y.

1893, With McKim, Mead & White, New York City. 1894, Formed partnership with A. W. Lord as architects.

HILDRETH, RUSSELL WADSWORTH, E.M., . . . 1885.
R. W. Hildreth & Co., Civil and Inspecting Engineers, Specialties Steam and Street Railways and Bridges, 50 Broadway, and 25 Madison Avenue, New York City.

Assistant Engineer in employ of George S. Morison from October 1, 1885, to January 1, 1890, on new Omaha Bridge (U. P. Ry.), Nebraska City Bridge (C., B. & Q. R. R.), Sioux City Bridge (C. & N. W. R. R.) over the Missouri River; the Willamette River Bridge, Portland, Ore. (O., R. & N. Co.); the Ohio River Bridge at Cairo (Ill. Cent. R. R.), and other structuses.

Present co-partnership formed January 1, 1890, and since then have had charge of the following structures: Mill and shop inspection and superintendence of erection of Red Rock Cantilever (660 feet clear span), Colorado River Crossing, A. & P. R. R.; Susquehanna River Bridge, Panther Creek Viaduct, and other bridges Wilkes-Barre & Eastern R. R.; 155th Street Viaduct and Central Drawbridge (McCoomb's Dam), New York City, and others. As Consulting Engineers, responsible for design, bridges, Wilkes-Barre & Eastern R. R., including Susquehanna River Bridge and Panther Creek Viaduct, Chattahoochee River Bridge (including 330 feet draw), S. A. & M. R. R., Union Trust Company Building, Detroit, Mich. (a thirteen story, fire-proof, office building), and others.

HILDRETH, WALTER EDWARDS, C.E., E.M., . . . 1877.
Metropolitan Hotel, 584 Broadway, New York City.

HILL, WILLIAM, C.E., ... 1882.
Assistant Superintendent Collins Company, Box 196, Collinsville, Conn.

One year practical experience in manufacture of crucible steel. Two years draughtsman and assistant to master mechanic of company manufacturing crucible steel, bar-iron, edge tools, plows and wrenches. Engineer in charge of reconstruction of dam 600 feet long, 32 feet high, at Otis, Mass. 1886 to date, Assistant Superintendent for the Collins Company, manufacturing principally edge tools. November 1st, 1891, appointed agent of the Collins Company, with general charge of plant at Collinsville, Conn., employing 650 men.

HINMAN, BERTRAND CHASE, PH.B., A.M. (1892), . . 1890.
273 McDonough Street, Brooklyn, and Mansville, Jefferson County, N. Y.

Since June, 1890, Chemist to the Iron Clad Manufacturing Company, engaged in the manufacture of sheet-iron enamelled ware.

HOLBROOK, FRANCIS NEWBERRY, C.E., ... 1876.
42 Pine Street, New York City, and Box 395, Tarrytown, N. Y.

From fall, 1876, to spring, 1880, Assistant Assay Laboratory School of Mines. Spring and Summer on Geological Survey, West Texas. Then to 1884, spring, Superintendent Corralitos Co., Chihuahua, Mexico. 1884–87, expert work, office El Paso,

Texas. Summer and fall, 1887, Superintendent of United Verde Copper Company, Arizona. 1888, spring, on geological work for the Southern Pacific Company in West Texas. Summer and fall, running gold mine and mill for self in Arizona. 1889–90, Manager for U. S. Circuit Court in suit between the Con. Kansas City Smelting and Refining Company and the Guadalupe Company, in Nuevo Leon, Mexico. 1890 to February, 1891, employed by the Compañia Métalurgica Mexicana. March and April, 1891, charge of copper smelter, Tucson, Arizona. Expert work until 1892, when returned to Comp. Metal., Mexico.

HOLDEN, EDWARD HENRY, C. E., ... 1878.

1074 Boston Avenue, New York City.

HOLLERITH, HERMAN, E.M., PH.D. (1890), . . . 1879.

Electrician and Expert, 501 F. St., Washington, D. C.

HOLLICK, ARTHUR, PH.B., ... 1879.

Columbia College, New York City and New Brighton, N. Y.

Superintendent Mexican Mine, Mariposa, Cal., 1880. New York City Health Department Inspector from 1881–90. Sanitary Engineer from 1890–91. Special Inspector, 1892. Special Expert and Inspector of Offensive Trades, New York State Board of Health, both in consultation and field work, from 1883 to date. Board of Health, Village of New Brighton; 1886–92, a member of the Board. Board of Health, Long Island City, Sanitary Adviser, 1890. In general practice as a sanitarian from 1883 to date. U. S. Geological Survey—engaged in collecting specimens in the Territories, in 1882. Appointed Fellow in Geology, Columbia College, January, 1890; reappointed, 1891; Assist., 1892. 1893, Tutor in Geology. Recording Sec'y Torrey Botanical Club, N. Y., 1883–88. Secretary Natural Science Association of Staten Island, 1881 to date. Associate Editor, *Bulletin*, Torrey Botanical Club. 1888 to date, Librarian New York Academy of Sciences, 1894.

HOLLIS, HENRY LEONARD, E.M., ... 1885.

1232 The Rookery, and 3004 Prairie Avenue, Chicago, Ill.,

1885, Assistant Chemist Edgar Thomson Steel Works. 1885–87, Assistant Chemist, North Chicago Rolling Mill Company. 1887–90, Chief Chemist, North Chicago Rolling Mill Company, which, in 1889, became by consolidation part of the Illinois Steel Company. 1890, member of firm of Rattle, Nye & Hollis, Analytical Chemists and Mining Engineers. 1893, Member of firm of H. L. Hollis & Co., Analytical Chemists and Mining Engineers.

HOLLIS, WILLIAM, C.E., ... 1878.

Box 109, Eagle Pass, Texas. Agent for Alamo and Coahuila Coal Cos.

HOLT, MARMADUKE BURRELL, E.M., ... 1889.

Silverton, Colo., and 287 Lexington Ave., New York City.

1889–90, Student in course of Electrical Engineering, School of Mines. 1890–91, with Aspen Mining and Smelting Company, serving as Mining and Electrical Engineer. 1891 to fall of 1892, Agent and Electrical Engineer with the "C. and C." Electric Motor Co., N. Y. City and Denver. 1892–93, Assayer Colorado Smelting Co., Pueblo, Colo.

HOOKER, WILLIAM AUGUSTUS, A.B., A.M., E.M., . . 1869.

Hooker & Lawrence, 145 Broadway, New York City.

HOOPER, FRANK CYRUS, MET. ENG., ... 1890.

North River Garnet Co., Ticonderoga, N. Y.

1890–1891, Assistant Engineer De Lamar Mining Co., Limited. 1892–93, American Graphite Co. Spring, 1893, Investigation and report on Sisal Hemp Industry in The Bahamas for The Inagua Fibre Co. Summer and Fall, Erection of Concentrating Plant in Adirondacks.

HOPKE, THEODORE M., PH.B., ... 1880.

Care McKeesport Supply Co., and 408 Shaw Ave., McKeesport, Pa.

August, 1889, November, 1881, Analytical Chemist with Ledoux & Co., New York. November, 1881, to November, 1885, Member of the firm of Elliott, Hopke & Mattison, Analytical and Consulting Chemists and Assayers. July, 1886, to November, 1889, Chemist for Linden Steel Co., of Pittsburgh, Pa., also had charge of Physical testing department. November, 1889, to date, Manager Open-Hearth department of above Co., having full charge of manufacture of all grades of steel made by the company, also building of open-hearth furnaces. 1894, Secretary and Assistant to General Manager, McKeesport Supply Company.

HORNE, WILLIAM DODGE, PH.B.,. . . . . 1886.

Yonkers, N. Y.

June, 1886 to December, 1887, Chemist to Fulton Sugar Refinery, Brooklyn, N. Y. October, 1887 to December, 1887, Assistant Instructor in Chemistry, School of Mines, Columbia College. December, 1887, to June, 1888, Chemist to St. Louis Sugar Refinery, St. Louis, Mo. October, 1888, to October, 1889, Chemist to Standard Sugar Refinery, Boston, Mass. November, 1889, to present time, General Analytical and Consulting Chemist. January, 1890, to January, 1893, Consulting Chemist to Delaware Sugar House, Philadelphia. January to June, 1891, Instructor in Analytical Chemistry in Rutgers College, New Brunswick, N. J. May, 1893, to present time Consulting Chemist to National Sugar Refining Co., Yonkers, N. Y. Laboratory and office in New Brunswick from November, 1889, to September, 1893. From September, 1893, to present time in Yonkers, N. Y. In June, 1894, received from Columbia College the degree of Ph.D. in the Department of Chemistry and of Mechanical Engineering.

HOWE, EPENETUS, E.M. (Life Member), ... 1886.

Sierra Mojada, Coahuila, Mexico, and North Salem, Westchester County, N. Y.

Assayer and Chemist with the El Paso Smelting Co., and the Arzentine Works, Kansas, 1887–1889, and with Lacia Constancia Esmeralda Sierra Mojada Coahuila, Mexico, 1889. Assayer, Chemist and then Superintendent 1889 to date.

HOYT, WALTER LOWRIE, E.M., C.E., ... 1876.

Address unknown.

1877–1880, Chemist and Metallurgist at Smelting Works in Utah, Montana and Colorado. 1880–1884, Metallurgist with Omaha & Grant Smelting and Refining Co., Omaha, Neb. 1884, Mining Engineer with El Callao Gold Mining Co., Venezuela, S. A. 1885–1891, Superintendent St. Louis Smelting and Refining Co., St. Louis, Mo.

HUMBERT, WILLIAM SCOTT, E.M., ... 1883.

Niagara Falls, N. Y.

1883–1885, Surveys and location of Tunnel for New Croton Aqueduct. 1885–1887, Construction work new Croton Aqueduct and extensive Topographical Survey of the Croton Valley. 1887–1888, In charge of construction as Assistant Engineer at shafts No. 21, No. 22, and No. 23 New Croton Aqueduct (night shift). 1888 to 1891 Assistant Engineer in charge of the construction of two large dams and tunnels connecting the two basins of Double Reservoir "I," located 2 miles east of Brewster, N. Y., on the east Branch of the Croton River. 1891, Special Assistant Engineer Cataract Construction Company.

HUNT, FREDERICK FURNEAUX, E.M., C.E., . . . 1876.

77 Pine Street, New York City. and New Brighton, S. I.

HUNTINGTON, FREDERICK WOLCOTT, E.M., . . . 1885.

Address unknown.

HURLBUT, ELISHA DENISON, JR., C.E., ... 1890.
106 Hicks Street, Brooklyn, N. Y.
1890-91, at Columbia College Law School. 1891-93, Assistant in Mechanical Engineering, School of Mines.

HUTTON, FREDERICK REMSEN, A.B., A.M., E.M., C.E., PH.D. (Life Member), ... 1876.
Columbia College, and 296 Lexington Avenue, New York City.
1876-1877, Assistant in Engineering, School of Mines. 1877-1882, Instructor in Mechanical Engineering. 1882-1891, Adjunct Professor Mechanical Engineering. 1891, Professor Mechanical Engineering.

HYDE, F. S., PH.B., ... 1893.
215 Schermerhorn Street, Brooklyn, N. Y.
1893-94, Investigations in Glass, for L. C. Tiffany, New York City. Assistant Chemist, Brooklyn Department of Health, May, 1894, to date.

I.

IHLSENG, AXEL OLAF, B.S., E.M., C.E., ... 1877.
Carthage, Mo.
1877-1882, Chief Chemist, Havemeyer Sugar Refining Co., Brooklyn, E. D. 1882-1890, U. S. Dep. Mining Surveyor, District of Colorado. 1882-1883, Chemist and Assayer, La Plata Smelter, Leadville, Colo. 1883, Metallurgist, Martha Rose Smelter, Silverton, Colo. 1884, Assayer, Stoiber Sampling Works, Silverton, Colo. 1885, Duyckinck, Schuyler & Ihlseng, Ore Samplers, Silverton, Colo. 1886-1890, Manager of Mt. Queen Mining Co, Reliance Mining Co., Brown Mining Co., and the Hale Mines, Silverton, Colo. 1890-1892, Operating Zincite Mine and others near Webb City, Nevada, and in constructing concentrating plants. Manager Pleasant Valley Mines, Carthage, Mo.

IHLSENG, MAGNUS C., E.M., C.E., PH.D., . . . 1875.
State College, Pa.

ILES, MALVERN WELLS, PH.B., PH.D. (Life Member), . 1875.
Superintendent Globe Smelting Co., Denver, Colo.

INGERSOLL, WILLIAM HALSEY, A.B., A.M., LL.B., E.M., (Life Member), ... 1870.
Northport, Suffolk County, N. Y.
1875-1878, Assistant in Engineering, Columbia College. 1878-1881, Assistant in Mechanics and Astronomy. 1881-1887, Manufacturing tin-ware, Portland, Conn. 1887-date, Incapacitated from practice by lack of health.

INGRAM, EDWARD LANNING, C.E., ... 1885.
Room 14, 110 Pearl Street, and (for mail) 109 Prospect Avenue, Buffalo, N. Y.
1885-86, U. S. Inspector of River and Harbor Improvements, Delaware. 1887-89, U. S. Surveyor and Inspector, River and Harbor Improvements, New York and New Jersey. 1890-91, U. S. Assistant Engineer, River and Harbor Improvements, Florida. 1891-94, Principal Assistant Engineer, International Boundary Survey, United States and Mexico.

J.

JACKSON, OSWALD, C.E., ... 1892.
550 Park Ave., N. Y. City.
1892-93, Office of Engineer M. W., U. R. R.'s of N. J. Div. P. R. R. 1893, Engineer on Corps of Prin. Asst. Engineer, U. R. R.'s of N. J. Div. P. R. R.

JACOBS, DAVID MARK, PH.B., ... 1887.
R. J. Jacobs, 41 New St., and 30 W. Thirty-eighth St., N. Y. City.

JACOBS, SOLOMON JOSEPH, PH.B., ... 1887.
R. J. Jacobs, 41 New St., and 30 W. Thirty-eighth St., N. Y. City.

JANEWAY, JOHN HOWELL, E.M., ... 1886.
John A. Roebling's Sons Co., and 124 West State St., Trenton, N. J.
1886, Underground and Surface Surveyor for Cooper, Hewitt & Co. 1887-1891, Draughtsman and Designer and Constructing Engineer of Wire Rope Tramways in Montana, Oregon, Alaska, and California for the Trenton Iron Co., Trenton, N. J.

JENKS, ARTHUR WILTON, E.M., ... 1886.
Superintendent Balbach Smelting and Refining Co., Newark, N. J.
Summer 1886, New Jersey on Geological Work. 1886-1887, In Cerro de Pasco, Peru, S. A. Assayer and Chemist to the commission examining that silver mining district. Spring, 1887, In New York, Chemist with Ledoux & Co. 1887-1888, In Aurora, Ill., Assistant at the works of the Chicago and Aurora Smelting and Refining Company. Summer and Fall 1888, In Dutch Guiana, S. A., Assayer and Assistant in the examination of gold deposits. Fall 1888 to 1893, in Aurora, Ills., Assistant Superintendent at the Aurora Works of the Chicago and Aurora Smelting and Refining Co. 1893, Superintendent Kootenay Reduction Co. 1894, Superintendent Balbach Smelting and Refining Co., Jersey City, N. J.

JEUP, BERNARD JOHN THEODORE, C.E., ... 1887.
Assistant City Engineer, 119 Walcott St., Indianapolis, Ind.

JOHNSON, ARTHUR GALE, E.M., ... 1885.
Jensen, Utah.

JOHNSON, ELIAS MATTISON, PH.B., ... 1878.
Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSON, GILBERT HENRY, PH.B., ... 1878.
Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JOHNSON, ISAAC BRADLEY, E.M., ... 1879.
Isaac G. Johnson & Co., Spuyten Duyvil, N. Y.

JONES, JOHN ELMER, E.M., ... 1893.
Asst. Supt. Mill Creek Coal Co., New Boston, Pa., and Hazleton, Pa.

JONES, WILLIAM DENISON, PH.B., ... 1888.
Hecker, Jones, Jewell Milling Co., 206 Produce Exchange, N. Y. City, and 62 Clark Street, Brooklyn, N. Y.

JOPLING, REGINALD FURNESS, E.M., ... 1889.
Jopling & Escobar, Engrs., Room 508 Cuyahoga Bldg., Cleveland, O.
November, 1889, to February, 1890, Chemist, Otis Steel Co., Ltd. February, 1890-92, Assistant Manager American Wire Co. Vice-president of same, January, 1892.

JOUET, CAVALIER HARGRAVE, PH.B., ... 1882.
104 John Street, New York City, and Roselle, N. J.
Analytical Chemist with Ledoux & Ricketts, 1882-1875. Analytical Chemist with G. H. Nichols & Co., Acid Manufacturers at Laurel Hill, L. I., from 1885-1888. Work comprising analyses of their various products and a partial supervision of their manufacture. Analytical Chemist from 1888 to present time with Ricketts & Banks.

K.

KASTNER, J. C., PH.B, ... 1894.
72 E. Ninety-second Street, New York City.

KELLY, WILLIAM, A.B., E.M., ... 1877.
Vulcan, Dickinson Co., Mich.

1877, '79, '80, Assistant Superintendent, Chemical Copper Co., Phœnixville, Pa. 1878, Chemist, Himrod Furnace Co., Youngstown, Ohio. 1881–84, Superintendent, Kemble Coal and Iron Co., Riddlesburg, Pa.; 1885, Superintendent, Glamorgan Iron Co., Lewistown, Pa.; 1886–89, Superintendent, Kemble Iron Co., Riddlesburg, Pa.; In charge of Blast-furnaces, Coal Mines, Coke Ovens, Ore Mines, Quarries, Railroads, etc. 1889 to date, General Superintendent and Gen'l Manager Penn Iron Mining Co. Vulcan, Mich.; In charge of Iron-ore Mines on the Menominee Range, Lake Superior. Also, 1885–89, President Board of Examiners of Bituminous Mine Inspectors of Pennsylvania.

KEMP, JAMES FURMAN, A.B., E.M., ... 1884.
Prof. Geology, Columbia College, School of Mines, and 211 W. 139th St., New York City.

Several months with the Rand Drill Co., 1883–1884. Private Assistant to Prof. J. S. Newberry, 1884–85. Student of Geology and Mineralogy at the Universities of Leipzig and Munich, Germany, 1885–86. Instructor in Geology at Cornell, 1886–88. Assistant Professor of Geology and Mineralogy, 1888–91, and Secretary of the Faculty, 1888–89. Have travelled in the West in 1889, and for two summers past have been working on the Geology of the Lake Champlain region and Adirondacks. Am especially engaged on Inorganic and Economic Geology. 1891, Adjunct Professor of Geology, School of Mines, Columbia College. Professor, 1892.

KINSEY, FRANK WILMARTH, C.E., ... 1891.
50 Broadway, New York City, and 10 South Street, Newark, N. J.

Assistant to Engineers' Rapid-Transit Commission, 1891–92. Engineer of Construction East Providence Water Works, 1892. Designing Engineer with S. M. Gray, 1892–93. 1893, Manager for R. W. Hildreth & Co.

KISSAM, HENRY SNYDER, PH.B., ... 1886.
Architect, Psi Upsilon Club, 33 W. Forty-second St., N. Y. City.

1888–89, Manager of Office of Pickles & Sutton, Architects, Tacoma, Washington. 1889–90, Practicing Architecture with P. W. Morris under firm name of Kissam & Morris, Tacoma, Washington. 1890–92, Practicing Architecture alone under name of Henry Snyder Kissam, Tacoma, Washington. 1892, Practicing Architecture with Jno. G. Proctor, under firm name of Proctor & Kissam, Tacoma, Washington. During 1893, in New York City, as Student of Special Construction.

KLEPETKO, F., E.M., ... 1880.
General Manager Boston and Montana Consolidated Copper and Mining Company, Great Falls, Montana.

Superintendent Smelting Department, Tamarack, Osceola Copper Manufacturing Company, Dollar Bay, Mich. At present Superintendent of Construction of the Great Falls Smelter, for the Boston and Montana Consolidated Copper and Silver Mining Company. Address, Great Falls, Montana.

KOCH, EDWARD CABOT, E.M., ... 1879.
Assistant General Manager, Elmore Gold Co., Limited, Rocky Bar, Idaho, and 160 E. Fifty-sixth Street, New York City.

1880, 1881, 1882, Assayer and Chemist at Smelters, Leadville, Colo. 1883–1888, Surveyor and Assistant Superintendent, L. A. G. Mg. Co., Colo. 1889 to 1892, Assistant General Manager E. G. Co., Ltd., and V. G. Co., Ltd., Rocky Bar, Idaho. 1892 to date, examining mining properties.

KOEN, JOSEPH JOHN, C.E., ... 1888.

Board of Health, 301 Mott Street, New York City, and Pearsalls, N. Y.

1889–90, Computer on New Croton Aqueduct. 1890–91, to date, Sanitary Engineer on New York City Board of Health.

KUNHARDT, WHEATON BRADISH, E.M. (Life Member), . 1880.

Capenter Steel Co., 1 Broadway and 32 Beaver Street, New York City.

1880–82, Travel and Study in the West and in Europe. 1883–88, Engineer for the Bower-Barff Rustless Iron Co., and Assistant of Geo. W. Maynard in consulting work on Iron-mines and Ore-dressing. 1888–89, First Assistant Engineer of the Boston Heating Co. 1890–91, Diamond Drill Exploration of Coal Deposits in Rhode Island. Report on Direct Steel Processes and on Magnetic Separation for Iron-ores. Acting Secretary of the American Institute of Mining Engineers for four months. 1893, President of the Osceola Placer Mining Company. 1874, with Carpenter Steel Co., 1 Broadway, New York City.

KURTZ, EDWARD LAURENCE, E.M., ... 1893.

In Europe, 1894.

L.

LACOMBE, CHARLES FREDERICK, E.M., ... 1885.

The Mountain Electric Co., P. O. Box 1545, and 535–536 Seventeenth Street, and 1811 Grant Avenue, Denver, Colo. Also, University Club, New York City.

1885 to 1886, Assayer and Surveyor and Foreman of Lucky Boy and South Galena Mines, in Bingham, Utah. 1886 to 1888, Assistant Instructor in Assaying, and Fellow in Chemistry, School of Mines, Columbia College, N. Y. 1888 to 1890, Examining Gold and Silver Mines in Colorado, Utah, Montana, Arizona and Old Mexico. 1890, Testing Electrical Apparatus in Virginia City, Nevada. 1890, Manager of the Gilpin Co. Light, Heat and Power Co., Central City, Colo. 1890 to date, President and Manager, The Mountain Electric Co. Specialty, Installing Electric Light and Power Stations, and adapting electric light and power for mining purposes.

LAHEY, JOSEPH, E.M., ... 1887.

162 E. Seventy-eighth Street, New York City.

LAHEY, RICHARD, E.M., ... 1887.

Wilson Bros. & Co., Drexel Building, Philadelphia, and 162 E. Seventy-eighth Street, New York City.

LAMB, ANDREW JOHNSON, E.M., ... 1884.

L. & N. R. R. Co., Birmingham, Ala.

June, 1884, to June, 1887, New York Croton Aqueduct, Draughtsman. June, 1887, to Sept., 1890, Assistant Engineer, L. & N. Railroad. Sept., 1890, to June, 1891, Assistant Roadmaster, Knox. Div., L. & N. Railroad. June, 1871, to date, Assistant Engineer L. & N. R. R.

LANGMUIR, A. C., ... 1893.

Address unknown.

LANGTHORN, J. S. (Associate), ... 1891.

Superintendent's Office, Jamaica and Brooklyn Electric Road Company, Jamaica, L. I., N. Y., and 196 Joralemon Street, Brooklyn, N. Y.

LAWRENCE, BENJAMIN BOWDEN, E.M., ... 1878.

Hooker & Lawrence, 810 Boston Ave., Denver, Colo.

1878–84, Superintendent, Montezuma S. M. Co., and of other mines of Summit Co., Colo. 1884–91, Lessee and Operator of Mayflower and Pelican-Dives Mines, Clear Creek Co., Colo. In 1886, Formed partnership with W. A. Hooker, E.M., Class of 1869, with office at 145 Broadway, as Consulting Mining Engineers. I make a specialty of operating under lease or otherwise, true fissure Gold and Silver Mines, also Concentration of Gold-silver ores. 1893–1894, Georgetown, Colo., at the Pelican-Dives Mines. 1895, Manager the Perigo Gold Mines, Colo.

LEARY, DANIEL JAMES, C.E., E.M., ... 1881.
43 E. Twenty-fifth Street, New York City.

1882 to date, Constructing Highway and Railroad Bridges, Wharves, Docks, Dredging and Harbor Improvements generally, in vicinity of New York City, as Designing and Supervising Engineer, as well as Contractor in most instances. In general, make a specialty of both Engineering and Constructing work, or Engineering work alone, in this branch of the profession.

LEARY, GEORGE, C.E., ... 1891.
43 E. Twenty-fifth Street, New York City.

LEAVENS, HARRY WENMAN, E.M., ... 1875.
Salt Lake City, Utah.

LEBOUTILLIER, CLEMENT, PH.B., ... 1881.
High Bridge, New Jersey.

1884–7, Assistant Chemist, Cambria Iron Co. 1887–92, Chemist, Eliza Furnace. March, '92, to date, Chemist, Taylor Iron and Steel Company.

LEDERLE, ERNST JOSEPH, PH.B., ... 1886.
Assistant Chemist, New York City Health Dept., 42 Bleecker St., and 120 W. 90th St., New York City.

1886–87, Hon. Fellow Quant. Anal. and Assist. Intr. Gen. Chemistry, School of Mines. 1887–88, Chemist, Cranmoor Farm, Tom's River, N. J. 1888–89, Asst. Chemist, New York City Health Dept. 1890–91. Chemist and Supt., Reed & Carnrick, New York. 1891–92, as above, specialties, food and food preparations. Lecturer on Chemistry and Director of the Chemical Laboratory, New York Dental School.

LEDOUX, ALBERT REID, M.S., PH.D. (Associate), . . 1874.
Ledoux & Co., 9 Cliff Street, New York City.

LEE, GEORGE BARSTOW, E.M., ... 1885.
Superintendent Guggenheim Smelting Co., Maurer, Middlesex Co., N. J.

1885, Assayer, Butte, Montana. 1886–87, Assayer, Kansas City Smelting and Refining Co., Argantine, Kan. 1887–90, Assistant Superintendent, Rio Grande Smelting Co., Socorro, New Mexico. 1890–93, Superintendent, Rio Grande Smelting Co., Socorro, New Mexico. 1894, Superintendent Guggenheim Smelting Co.

LEGGETT, THOMAS HAIGHT, E.M., ... 1879.
Standard Consolidated Mining Co., Bodie, Mono County, Cal., also 310 Pine Street, San Francisco, Cal.

1880, Assistant Engineer, New York River and Harbor Surveys. 1881–1883, Superintendent of Mining Properties in the Batopilas District, Chihuahua, Mexico. 1884, Travelling in the West, through the principal Mining Camps, Butte, Leadville, etc. 1884–1887, Mining Engineer to the New York and Honduras Rosario Mining Co., at San Juancito, Honduras. 1888, Manager of Mudsill Mining Co., Fairplay, Colo.; office, 23 Bucklersbury, London, E. C. 1889–1890, General Manager, Darien Gold Mining Co., Ltd., of Cana, Rep. of Colombia. 1891–93, President and Manager Standard Consolidated Mining Co.

LENOX, LIONEL REMOND, PH.B., ... 1888.
Assistant Professor Chemistry, Leland Stanford, Jr., University, Palo Alto, California.

After three years' work in the School of Mines, and previous to my senior year, I was respectively in: 1887, three months Assistant Chemist to Fulton Sugar Refinery. 1887, six months Assistant Chemist to Bethlehem Iron Co. 1888-89, Instructor in Qualitative Analysis and Assaying, Lehigh University. 1889-91, Instructor in Quantitative Analysis and Industrial Chemistry, Lehigh University. 1892-93, Chemist, Bureau of Ordnance, Washington, D. C.

LEVY, ALBERT LINCOLN, E.M., ... 1890.
Fischel & Levy, Hartford, Conn.

LIBAIRE, EDWARD WILLIAM, C.E., ... 1894.
150 W. Forty-ninth Street, New York City.

LIEBMANN, ALFRED, C.E., ... 1893.
38 East Seventy-second Street, New York City.

LILLIENDAHL, ALFRED WHIPPLE, E.M. (Life Member), 1883.
Superintendent, Mazapil Copper Co. (Ltd.), Concepcion del Oro, Estado de Zacatecas, Mexico.

1883-85, Assistant Supt. Aurora Smelting and Refining Co., Aurora, Ill. 1885-87. Assistant Supt. Grande Milling and Refining Co., Guanajuato, Mexico. 1888-93, Superintendent of the Mazapil Copper Co., Ltd., Concepcion del Oro, Zacatecas, Mexico. Superintendent, Coahuila and Zacatecas Railroad.

LILLIENDAHL, FRANK ARMSTRONG, E.M., . . . 1891.
Assistant Superintendent and Metallurgist, Mazapil Copper Co. (Ltd.), Concepcion del Oro, Estado de Zacatecas, Mexico, (via Laredo, via Saltillo).

1891-93, as above.

LILLIE, SAMUEL MORRIS, E.M., ... 1874.
328 Chestnut Street, Philadelphia, Pa.

1874-75, Chemist, Kings County Refining Co., Green Point, L. I. 1876-85, Chemist, Franklin Sugar Refinery, Philadelphia, Pa. 1886-1887, Sugar Engineer and Chemist. 1888, 1889 and 1890, Vice-President and Manager of "The Sugar Apparatus Manufacturing Co.," a Company organized under the Laws of Pennsylvania, to operate under his patents. 1891, President of said Company.

LIPPS, HENRY, JR., C.E., ... 1888.
Address unknown.

From July, 1888, to August, 1889, Assistant Engineer Maint. of Way, Dep. R. & D. R.R., W. N. C. & Va. Mid. Div. August, 1889, to January, 1890, Supervisor Track, N. C. Div. R. & D. R.R. January, 1890, to date. Engineer Maint. of Way, N. C. Div. R. & D. R.R.

LITTLE, WILLARD PARKER, E.M., PH.B., . . . 1881.
Architect, 28 West Twenty-Third Street, New York City.

LIVINGSTON, ARCHIBALD ROGERS, C.E., ... 1891.
20 North Washington Square, New York City.

Since November, 1891, in employ of Lackawanna I. & S. Co., Scranton, Pa.

LONGACRE, LINDSAY B., M.E., ... 1892.
Spuyten Duyvil, N. Y.

LORD, FREDERICK REUBEN, C.E., ... 1892.
General Manager, Clifton Coal Company, Bay Street cor. Vanderbilt Ave., Clifton, and Box 228 Stapleton P. O., Richmond County, N. Y.

LOVE, EDWARD GURLEY, A.M., PH.B., PH.D., . . 1876.
Analytical and Consulting Chemist, Gas Examiner, Department Public Works, 122 Bowery, and 80 E. 55th Street, New York City.

LUDLOW, EDWIN, E.M., ... 1879.
Superintendent Choctaw Coal and Railway Company, Hartshorn, Indian Territory.

1879–81, Assistant Engineer in charge of hydrographic work on Delaware River under U. S. Engineer. 1881, Assistant Engineer Mexican National Railroad, Mexico. 1882–89, Assistant Superintendent, then Superintendent, for Pennsylvania Railroad coal-mines at Shamokin, Pa. 1889 to date, Superintendent of Mines, Choctaw Coal and Railroad Company, Hartshorn, Indian Territory.

LUQUER, LEA MCILVAINE, C.E., Ph.D., ... 1887.
Tutor in Mineralogy, School of Mines, N. Y. City, and Bedford, N. Y.

Summer of 1887, Assistant in Geodetic Surveying with Professor Rees. Summer of 1887, Assistant in Surveying with Professor Monroe. Summer of 1888, Assistant in Geodetic Surveying with Professor Rees. 1887–90, Fellow in Mineralogy, School of Mines. 1890, Assistant in Mineralogy, School of Mines. 1891 to date, Tutor in Mineralogy, School of Mines.

LUQUER, THATCHER TAYLOR PAYNE, C.E., E.E. (1892), . 1889.
256 Broadway, N. Y. City, and 618 Henry St., Brooklyn, N. Y.

1890, Fellow in Engineering. 1890–91, Fellow in Surveying and Practical Mining. 1891, Assistant in Mining, Columbia College, School of Mines. 1892, with H. Ward Leonard & Co., New York City. 1893, Engineer, Union Electric Co., N. Y. City. 1894, Engineer the Fiter Conduit Company.

LUSK, GRAHAM, PH.B., PH.D. (Munich, 1891), . . 1887.
Assistant Professor of Physiology at the Yale Medical School, New Haven, Conn. Address: 47 East Thirty-fourth St., N. Y. City.

1887–1888, Student at Munich. 1889, Student at Munich; also at Bellevue Hospital Medical College, N. Y. 1890, Studied at Bellevue; afterwards in Munich. 1891, Studied at Munich; and was later appointed Instructor of Physiology at the Yale Medical School. 1892, Assistant Professor of Physiology.

LUTTGEN, EBERHARD, PH.B., ... 1884.
Wissahickon Chemical Works, Ambler and Chelten Hills, Wyncote P.O., Pa.

1884–85, Assistant Chemist, Crane Iron Company, Catasauqua, Pa. 1885 to date, Chemist and Manager, Keasbey & Mattison's Chemical Works, Ambler, Pa. Specialty, manufacture of magnesia.

LYMAN, FRANK, A.B., M.E., ... 1878.
Deputy Commissioner City Works, Room 15 Municipal Building, and 50 Remsen Street, Brooklyn, N. Y.

M.

MCCULLOH, EDWIN AUSTIN, PH.B., ... 1878.
Glencoe, Md.

McILHINEY, PARKER C., A.M., PH.D., ... 1892.
School of Mines, Columbia College, New York City, and 72 Monticello Avenue, Jersey City, N. J.
Summer of 1892, Chemist Fibre Pipe Co. 1893-94, Hon. Asst. in Assaying. 1894, Asst. in Metallurgy.

McKENNA, CHARLES FRANCIS, PH.B., ... 1883.
221 Pearl Street and 144 West Ninety-ninth Street, New York City.
1883-84, Chemist Havemeyer Sugar Refining Company, Jersey City, N. J. 1885-86, Chemist Cambria Company, Johnstown, Pa. 1887-90, Chemist Edgewater Lime Works, Edgewater, N. J. 1890, Chemist Jas. J. McKenna & Bros., Brass Founders, 424, 426 East Twenty-third Street, New York City. 1893, Director, Physical Testing Department, Laboratories, Dr. G. E. Moore, 221 Pearl Street, New York City.

McKIM, ROBERT ALBERT, C.E., ... 1884.
Room 213, 280 Broadway, and 9 East Tenth St., New York City.
Assistant Engineer on New Croton Aqueduct. (Entered Aqueduct Engineer Corps as Chainman, in February, 1885.)

McLAUGHLIN, CHARLES SWAIN, PH.B., ... 1884.
874 Broadway and 2041 Fifth Avenue, New York City.

MacKAYE, HAROLD STEELE, C.E., ... 1887.
Westinghouse Electric and Mfg. Co., 120 Broadway, and 355 W. 145th Street, New York City.
Three months' work in New York Harbor in Army Corps of Engineers. One year's employment in the Office of Patent Solicitors. 1889-92, acting as Fourth Assistant Examiner of the U. S. Patent Office. Since July, 1892, Patent Counsel for Westinghouse Electric and Manufacturing Company.

MacTEAGUE, JOHN JOSEPH, E.M., ... 1883.
Address unknown.

MACLAY, JAMES, C.E., ... 1888.
Tutor in Mathematics, Columbia College, and 87 Union Street, Newark, N. J.

MAHONY, ARTHUR STUART, E.M., ... 1889.
51 West Ninety-fourth Street, New York City.
1890, First Assistant General Manager of the New Birmingham Iron and Land Company. 1891, Treasurer of the same company, also Chemist to the Tassie Belle Furnace, New Birmingham, Texas. 1893, Contractor.

MALUKOFF, A. J., ... 1893.
15 Winthrop Street, Boston, Mass.

MANNHEIM, HERMANN CHARLES, E.M., ... 1887.
254 Cumberland Street, Brooklyn, N. Y.

MANNHEIM, PAUL AUGUST LOUIS, E.M., ... 1885.
United Smelting and Refining Company, East Helena, Montana.

MARIÉ, LEON, E.M., ... 1885.
12 East Forty-sixth Street, New York City.

MARSH, JOHN ROLLIN, E.M., ... 1887.
Chief Engineer Indiana Bridge Co.
August 1, 1887, to date, as above.

MARTIN, EDWARD WARD (Associate), ... 1877.
Chemist, Board of Health, 301 Mott Street, New York City.

MASSA, CHARLES GRISWOLD, C.E., ... 1889.
143 W. 34th St., N. Y. City, and Fort Lee, N. J.

Oct. 1889 to date, on railroad and street railway construction, and miscellaneous work.

MASSA, LOUIS FERDINAND, C.E., ... 1890.
136 Liberty Street, New York City, and Fort Lee, N. J.

October, 1890, to 1892, shop practice, Maryland Steel Works, at Sparrow's Point, Md. as follows: October, 1890, to July, 1891, Machine-shop practice. July, 1891, to Sept., 1891, Bessemer-mill Construction. Sept., 1891, to Sept., 1892, Bessemer Rail-mill and Roll-house; Mechanical and Metallurgical Engineering. October, 1892, to 1893, Post-graduate Electrical Engineer at Columbia College. February, 1894, to date, Electric Constructing, W. H. Freeman & Co., 136 Liberty Street.

MASTERS, H. K., E.M., ... 1894.
173 Congress Street, Brooklyn, N. Y.

MATHIS, THEOPHILUS SMITH, E.M., ... 1879.
Engineer of Mines, and U. S. Surveyor General's Office, and 529 East St., Salt Lake City, Utah.

From January, 1890, to February, 1891, Assistant Draughtsman U. S. Surveyor General's Office, Salt Lake City, Utah. Since Feb., 1891, Chief Draughtsman of Mineral Division of said Office, and still holds that position.

MAYER, RALPH EDWARD, C.E., ... 1879.
Instructor in Mechanical Drawing, School of Mines, Columbia College, New York City.

MEISSNER, CARL AUGUST, PH.B., ... 1880.
Vanderbilt Steel and Iron Company, Box 565, and 2512 7th Ave., Birmingham, Ala.

One year, Assistant Chemist Joliet Steel Company. Three years, Chemist and Assistant Superintendent Brier Hill Iron and Coal Company, Youngstown, Ohio. One and a half years, Head Chemist Joliet Steel Company. Three years, Manager Sterling Iron and R'wy Company, Sterlington, N. Y. At present, Vice President and General Manager of the Vanderbilt Steel and Iron Company, Birmingham, Ala., after having personally organized this company. President, Jefferson County Mining and Quarrying Company.

MELLISS, D. ERNEST, A.M., PH.D. (Associate), . . . 1868.
Price's Building, 524 Sacramento Street, San Francisco, Cal.

Student regular course, three years, School of Mines. Afterwards, two and a half years University of Goettingen, graduating Ph.D., in 1869. One year at University of Vienna. Since then, constantly occupied in civil and mining engineering. In 1873, was Chief Engineer in charge of Topographical and Geological Survey of Guanocaste and Nicoya for the Costa Rican Government. In 1881, Consulting Engineer to the Pacific Gas Light Company, of San Francisco, and in its interest studied the different gas-making systems in the United States, England, France and Belgium. Have made plans for and erected numerous gold, silver, copper and lead mines. Planned the Union Iron Works of San Francisco, and superintended their construction; also the Arctic Oil Works and several other industrial establishments on the Pacific Coast. Designed and built the Mazatlán Water Works in Mexico; the Hydraulic Press Brick Works, of California, the largest establishment of its class on the

Pacific Coast. Four years in Central America and Mexico. Was Administrator of San José de las Bocas and Consulting Engineer to Guadalupe de los Reyes, the most successful silver mine of Sinaloa. Now Consulting Engineer in San Francisco, and particularly occupied in that capacity for the Olympic Salt Water Company, whose works are now being erected under his supervision and according to his plans.

MERRILL, FREDERICK JAMES HAMILTON, PH.B., PH.D., . 1885.
State Museum, and 2 Sprague Place, Albany, N. Y.

1885-87, Assistant on the Geological Survey of New Jersey. 1886-90, Fellow in Geology, Columbia College. 1890 to date, Assistant State Geologist and Assistant Director of the New York State Museum, Albany, N. Y.

MERRITT, JAMES HAVILAND, PH.B., A.M., . . . 1880.
Care of Grenville Temple Snelling Company, 41 E. 49th St., New York City, and 3 Munroe Place, Brooklyn, N. Y.

From 1881-1888, Chemist to the Bradley White Lead Co. In 1889, entered the School of Mines as Post Graduate in the course of Architecture. 1892-93, Architectural Study.

MERWIN, HUBERT JOHN, E.M., ... 1879.
The American Association (Ltd.), Middlesborough, Ky.

MERZ, EUGENE, M.E., ... 1892.
Box 112, and 143 Littleton Ave., Newark, N. J.

MESEROLE, WALTER MONFORT, C.E., ... 1881.
189 Montague St., and 2789 Atlantic Avenue, Brooklyn, N. Y.

1881, Transitman and Topographer Continental Railway Co. 1881-83, Assist. Eng. in Construction N. Y., West Shore and Buffalo Ry. 1884-85. Division Engin'r Maintenance of Way; 1885, Chief Engineer Catskill Mtn. and Cairo Railway. 1885, in charge Topographical Survey for Kings County Charities' Commission. 1886 to date, in General Practice, located at Brooklyn, N. Y. Specialties: Improvement and Development of Real Estate and Surveying for Legal and Construction Purposes; City Surveyor of the City of Brooklyn; Chief Engineer South Brooklyn R. R. and Terminal Company, German-American Improvement Co., and Hancock and State Line Railway Company.

MESSITER, E. H., C.E., ... 1894.
Care of Guggenheim Smelting Co., Perth Amboy, N. J.

MEYER, HERMAN HENRY BERNARD, E.M., . . . 1885.
539 W. Twentieth Street, New York City, and 844 Putnam Avenue, Brooklyn, N. Y.

Surveying, Field and Office work at Pelham Park, Westchester Co., July to November, 1885. December, 1885 to date, Engineer for Oregon Iron Works, New York; designing and erecting machinery for manufacturing illuminating gas.

MIDDLETON, JOHN, C.E., ... 1887.
2789 Atlantic Avenue, and 14 Glenade Place, Brooklyn, N. Y.

1888 to date, Surveyor, Assistant to W. M. Meserole, C.E.

MILLER, CHARLES LEWIS, E.M., ... 1885.
Illinois Steel Company, 3179 Ashland Avenue, and 3609 Ellis Avenue, Chicago, Ill.

1886, Assistant Chemist Edgar Thomson Steel Works, Braddock, Pa. 1886-87, Chemist and Assistant Supt. Carbon Iron and Pipe Co., Parryville, Pa. 1887-90, Supt. The Missouri Furnace Co., St. Louis, Mo. 1890 to date, Supt. Blast Furnaces at Union Works of Illinois Steel Co., Chicago, Ill.

MILLER, CHARLES WATTS, E.M., ... 1884.
Box, 401, Aspen, Colo.

1884–1885, Metallurgical Engineer Hecla Bronze and Iron Works. 1885–1886, Assayer and Chemist, Aspen, Colo. 1886–1891, Mining Engineer and United States Deputy Mineral Surveyor, Aspen, Colo. General mining engineering business.

MILLER, EDMUND HOWD, PH.B., A.M.(1892), PH.D.(1894), 1891.
Assistant in Assaying, Columbia College School of Mines, and West Nyack, Rockland Co., N. Y.

1892–93, as above. 1894, Tutor in Analytical Chemistry and Assaying, School of Mines.

MILLER, RUDOLPH PHILIP, C.E., ... 1888.
Amagansett, N. Y.

1888–1890, Assistant to E. M. W., 1890 to 1894, Supervisor R. and D. Railway till April, 1894. August to November, 1894, with W. S. Miller, Builder, New York City. November, 1894, to date, with Long Island R. R. as transitman. November, 1894, to date, L. I R. R. Co.

MILLIKEN, GEORGE FANSHAWE, E.M., ... 1879.
Land Department, N. P. R. R., Tacoma, Wash., and Union League Club, New York City.

1879–1880, Superintendent "Milton Mining Company." 1880–1883, General Manager "Chester Mining Company." 1883–1887, In General Consulting Practice as Engineer. 1887–1890, General Manager "Costa Rica Mining Co., Ltd." 1890 to date, Consulting Engineer Northern Pacific Railroad.

MOLDEHNKE, RICHARD GEORGE GOTTLOB, E.M., PH.D., . 1885.
McConway & Torley Co., Forty-eighth Street and A. V. R.R., and 164 Home Street, Pittsburgh, Pa.

1885, '86, '87, Three Summer seasons with United States Coast and Geodetic Survey, New York and Philadelphia Harbors and Cape Cod, Mass., *Hydrographic Work*, Triangulation, Levelling, etc. 1885–1886, Winter, nine months, *Sanitary Engineering*, Inspector, etc., New York Association for Improvement of Condition of Poor. 1887–1889, *Electrical Engineering*, five months Mining Engineer Sprague Electric Railway and Motor Co., seven months Mechanical Engineer Crocker-Wheeler Motor Co., five months experimenting on patents taken out. 1889, Manufacturing for myself. Specialty in Machinists' Tools. 1889–1890, Professor Mechanical and Electrical Engineering, Michigan Mining School, Houghton, Mich. 1890 to date, Engineer McConway & Torley Co. (Manufacturers Janney Coupler, M. C. B. type). In addition to regular Engineering Work of Manufacturing Plant, conducting Metallurgical Investigations in line of Malleablization of Cast-iron. Specialties: Malleablized Cast-iron and Oil Fuel Gas.

MONELL, JOSEPH THOMPSON, C.E., ... 1889.
136 Liberty St., and 236 W. Twenty-second St., New York City.

1891, Electrical Engineering, Curtis Electrical Mfg. Co. 1892, Tutor in Astronomy, Columbia College.

MONTENEGRO, MANUEL RAFAEL, E.M., ... 1890.
539 W. 20th Street, New York City, and 53 Washington Street, Hoboken, N. J.

1890, Spiral Weld Tube Company, East Orange, N. J., and studying machine-shop practice. 1891–1892, engaged in the formation of mining companies. 1892 to date, Assistant Superintendent Oregon Iron Works, New York City.

MORA, MARIANO LUIS, C.E., ... 1891.
Columbia College, School of Mines, and 63 W. Seventieth Street, New York City.
Graduate Post-Graduate Course Electrical Engineering, 1894.

MORAN, DANIEL EDWARD, C.E., ... 1884.
Sooysmith & Co., Mills Building, and 26 W. Eighteenth Street, New York City.

MORGAN, WILLIAM FELLOWES, A.B., E.M. (Life Member), 1884.
Brooklyn Bridge Freezing and Storage Co., Arch 4 Brooklyn Bridge, New York City, and Short Hills, N. J.
1884–1888, Banking and Brokerage. 1888 to date, as above.

MORRIS, GOUVERNEUR WILLIAM, E.M., ... 1878.
Myers, Rutherford & Co., Corn Exchange Bank Building, and 123 W. Thirty-fourth Street, New York City.
Banker and Broker.

MOSLEY, RICHARD KEELER, PH.B., ... 1889.
Architect, 19 W. Twenty-fourth St., N. Y. City, and 139 Glenwood Avenue, East Orange, N. J.
From June, 1889, to January, 1893, worked as Draughtsman in the Offices of S. J. O'Conner, Carrère & Hastings, and Richard M. Hunt, of New York, and Benj. Silliman, of Yonkers, N. Y. Since January, 1893, practicing Architecture independently at the above address.

MOSES, ALFRED JOSEPH, E.M., PH.D., ... 1882.
Adj. Professor Mineralogy, Columbia College School of Mines, and 9 Henderson Place, New York City.
1882–1885, Assistant in Mineralogy, School of Mines. 1885–1890, Instructor in Mineralogy and Metallurgy. 1890 to date, Adjunct Professor of Mineralogy. Managing Editor SCHOOL OF MINES QUARTERLY.

MULFORD, ROBERT, E.M., ... 1884.
Frazer & Chalmers, Fulton and Union Streets, Chicago, Ill.
1890, Assistant Superintendent Rio del Oro Gold Co., Argentine Republic, S. A. 1891, Honduras? 1893, General Manager of The Kanimapoo Gold Mining Co., Limited, of Georgetown, Demerara, British Guiana, and am now in the employ of Frazer & Chalmers.

MÜLLER, GEORGE, PH.B., ... 1887.
Chemist, care Puget Sound Reduction Co., Everett, Washington.

MUNOZ DEL MONTE, ADOLPHO CARLOS, C.E., PH.B., . 1888.
212 S. Third Street, and Chestnut Hill, Philadelphia, Pa.
Returned from Europe, November, 1892, where, from June, 1891, travelled as a "McKim Fellow in Architecture."

MUNROE, HENRY SMITH, E.M., PH.D., ... 1869.
Professor Mining, Columbia College School of Mines, and 45 Sidney Place, Brooklyn, N. Y.
1869–1870, Post Graduate student in Chemistry and Economic Geology, School of Mines. 1870–1871, Assistant Geologist Ohio State Geological Survey. 1870–1872, Assistant Chemist, Department of Agriculture, Washington, D. C. 1872–1875, Assistant Geologist and Mining Engineer, Geological Survey of Yeddo, Japan. 1875–1876, Professor of Geology and Mining, University of Tokio, Japan. 1877–1891, Adjunct

Professor of Surveying and Practical Mining, and 1891, Professor of Mining, School of Mines, Columbia College, New York City. Specialties, Economic Geology, Ore Dressing, and Mining Engineering. 1881–1884, Manager, and 1890–1892, Vice-President American Institute Mining Engineers.

MUNROE, OTIS MORTIMER, PH.B., ... 1879.
Banker, De Soto, Mo.

MUNSELL, CHARLES EDWARD, PH.B., PH.D., . . . 1878.
F. W. Devoe & C. T. Raynolds Co., 283 Plymouth Street, Brooklyn, and Rye, N. Y.

November, 1878, with A. E. Foote, Mineral Dealer, Philadelphia. March, 1879, with T. A. Edison, Menlo Park, N. J. May, 1879, Chemist, Bushwick Chemical Works, Brooklyn, N. Y. October, 1879, Stencilographer and Celestyper, School of Mines, N. Y. January, 1880, to December, 1885, Milk Inspector, New York City Health Department. July, 1881, to May, 1883, State Milk Inspector, New York State Board of Health. 1886 to 1895, Analyst and Assistant Chemist, F. W. Devoe and C. T. Raynolds Co., New York City. Specialty, Paints and Colors.

MURPHY, HENRY MORGAN, E.M., ... 1878.
Murphy Varnish Co., Chestnut and McWhorter Streets, Newark, N. J.

MURPHY, JOHN GLENVILLE, E.M., C.E., ... 1877.
Address unknown.

Assistant Superintendent Orinoco Exploring and Mining Co., Gold Mine. Assistant Superintendent Callao Gold Mining Co. Territorial Geologist of Wyoming. Superintendent Esmeralda Mining Co., Black Hills, Dakota, Gold Mine. Superintendent New York and Lee Mountain Syndicate, Montana, Lead-Silver Mines. Has made professional examinations in nearly all parts of the United States, the Pachuca Silver and Jugnann Copper Districts in Mexico, and two and half years ago made a six months' trip in Colombia and Ecuador.

N.

NAPIER, ARTHUR HOWELL, E.M., ... 1884.
Sanitary Engineer, Lincoln Bldg., 1 Union Square, West, New York City, and 179 Harrison Street, Brooklyn, N. Y.

1884, Sanitary Engineer and Inspector for New York State "Tenement House Commission" and New York "Society for Improving Condition of Poor." 1885-1889-"Assistant Sanitary Engineer," New York Health Department. 1889 to date, Practicing as Sanitary Engineer, New York City.

NAVARRO, JUAN ADALBERTO, C.E., ... 1880.
Seminario No. 1, Mexico City, Mexico, and care Mexican Consul General, 35 Broadway, New York City.

1881–1882, Civil Engineering Course in Polytechnicum, Hanover, Germany. 1882–1884, Mexican Government Commissioner to study railway systems of Europe. 1885–1886, Railroad Inspector in Interoceanic Railroad, Mexico. 1886–1887, Assistant Compiler of Memoir published by Department of Public Works (*Fomento*), Mexico. 1887 to date, Engineer in charge of Surveys and Representative in Chiopas of the Mexican Land and Colonization Co.

NEFTEL, KNIGHT, C.E., PH.D., ... 1879.
115 Broadway, New York City.

NESMITH, JAMES, E.M., ... 1879.
256 Henry Street, Brooklyn, N. Y.

NEWBERRY, SPENCER BAIRD, E.M., PH.D., . . . 1878.
The Sandusky Portland Cement Co., Sandusky, Ohio.
1878–92, Professor of Chemistry Cornell University, Ithaca, N. Y.

NEWBERRY, WOLCOTT ELY, E.M., ... 1884.
Colorado Springs, Colorado.
1885–1885, Metallurgist, Casa Grande Co., Arizona. 1885–1886, Assistant Superintendent Cananea Mg. Co., Sonora, Mexico. 1886–1887, Superintendent Argentum Mining Co., Aspen, Colo. 1887, General Manager Aspen Mg. and Smelting Co., Aspen, Colo. 1888 to present time, General Manager Enterprise Mg. Co., Aspen, Colo. Superintendent Aspen Contract Mg. Co., Aspen, Colo. Superintendent Mutual Benefit Mining and Milling Co., Aspen, Colo. 1892, General Manager Isabella Gold Mining Company, Cripple Creek, Colorado. 1893, as above. 1894, Mining Engineer, Colorado Springs.

NEWBROUGH, WILLIAM, A.B., E.M., ... 1884.
122 W. Thirty-fourth Street. New York City.

NEWHOUSE, EDGAR LIEBER, E.M., ... 1886.
75 and 77 Worth Street, New York City.

NICHOLS, RALPH, E.M., C.E., ... 1877.
General Superintendent, The Comstock Tunnel Co., Sutro, Lynn Co., Nevada.
1878, Ore Sorter, Hukill Mine, Idaho Springs, Colo. Later, Assistant in F. E. Brown's Civil and Mining Engineering office, Georgetown, Colo. Later, Assayer and Chemist La Plata M. and S. Co., Leadville, Colo. Appointed U. S. Deputy Mineral Surveyor in 1879. 1879–82, Civil and Mining Engineer at Leadville, Colo., with following firms: Page, Nichols & Co., and Nichols & Dunham. Superintendent Farwell Cons. Mining Co.'s Gold Mill at Independence, Colo. Superintendent of the Big Pittsburg Cons. Mining Co., Leadville. 1883, Superintendent of the Viola Mining and Smelting Co. Later General Manager of same until 1891. Since then have been mining and working mines on lease. Examined mines in Colorado, Idaho, Nevada and Mexico. 1894, General Superintendent The Comstock Tunnel Co. Interested in mines in Colorado and Idaho, and am working mines in Idaho under lease. Have acted as ore buyer for the Cons. Kansas City S. and R. Co., and am at present representing the Globe S. and R. Co. in this State.

NOBLE, LOUIS SPENCER, E.M., ... 1885.
76 W. Ninetieth Street, New York City, and Leadville, Col.
1885–1889, Mining Engineer to Iron-Silver Mg. Co., and Nisi Prius Cons. Mg. Co., of Leadville, Colo. Also during 1889 Consulting, Reporting and Lawsuit work on other Colorado properties. 1889–1890, Superintendent of Mines and Mining Engineer to Constancia Mining and Smelting Co., at Sierra Mojada, Coahuila, Mexico. 1890–1891, Mining Engineer on Law-suit preparation, with Blue Bird Mining Co., Ltd., of Butte, Montana. Specialty, Lead, Silver and Gold Mines and Mining.

NOLAN, THOMAS, M.S., PH.B., ... 1884.
Nolan, Nolan & Stern, Architects, 504 Wilder Building, Rochester, New York.

NORRIS, DUDLEY HIRAM, E.M., ... 1877.
Address unknown.

NORRIS, ROBERT VAN ARSDALE, E.M., ... 1885.
Assistant Engineer, P. R. R., Dept. of Anthracite Coal, Room 28, First National Bank Building, and 24 S. Franklin Street, Wilkesbarre, Pa.

1885, Assistant in Practical Mining and Surveying, School of Mines. U. S. Inspector of Dredging, in charge of Maurice River Improvement, Millville, N. J. 1886, Chemist, Herman Behr, Manufacturer of Colors, Brooklyn, N. Y. June, 1886, to date, Assistant Engineer, Pennsylvania Railroad, Department of Anthracite Coal Collieries. Specialty, Mechanical Engineering of Collieries.

NORTON, LUCIEN HOLLEY, E.M., ... 1885.
Penna. Smelting Co., Sandy, Utah,

1887–1890, Engineering Office, N. Y., N. H. & W. R. R. Experience in Railroad Construction, Location and Preliminary Surveys, Office Work and General Surveying. 1890, Assayer and Engineer to West Indian New Gold Mining Corporation, San Domingo, West Indies. Experience in Free Melting of Gold-ores, Assaying, Surveying, etc. January, 1891-92, Assayer for Daly Mining Co., Park City, Utah. Experience in Assaying, General Analyses. Also Leaching of Silver-ores by the Russell Process. 1892 to date, as above.

NOYES, JAMES ATKINS, PH.B., A. B. (HARVARD, '83), (Life Member), ... 1878.
71 Sparks St., Cambridge, Mass.

NOYES, WILLIAM SKAATS, E.M., ... 1875
Shafter, Presidio County, Texas, and 2023 Summit St., Oakland, Cal.

1877–1879, Assayer for McCrackin Mining Co., Mohave Co., Arizona. 1879–1881, Foreman of Bodie Mill, for Bodie Coal Mining Co., Bodie, Cal. 1881–1883, Examining Mines for San Francisco Capitalists. 1883 to present time, Superintendent of Presidio Mining Co., and The Cibilo Creek Mill and Mining Co., Shafter, Presidio Co., Texas.

NYE, ALVAN CROCKER, PH.B., ... 1884.
Hayden Furn. Co., 1 West Thirty-fourth St., and 107 E. Seventieth Street, New York City.

1884–85, Draughtsman, C. C. Haight, Architect, New York City. 1885–90, Designer and Head Draughtsman, Herter Brothers, New York City. 1890 to date, Furniture Designer and Architect, The Tiffany Glass Co., New York City. 1892, Chief Designer as above.

O.

O'CONNOR, MICHAEL JOSEPH, E.M., PH.B., . . . 1881.
Architect (1884), 28 W. Twenty-third Street, New York City.

O'CONNOR, THOMAS DEVLIN, PH.B., ... 1881.
O'Connor & Elliott, 16 Exchange Place, and 12 E. Forty-fourth Street, New York City.

OLCOTT, EBEN ERSKINE, E.M., ... 1874.
Mining and Metallurgical Engineer, 18 Broadway, and 38 W. Thirty-ninth Street, New York City.

1874–75, Chemist to the Ore-Knob Copper Co, in charge of Hunt & Douglass Process. 1875–76, Assistant Supt Penna. Lead Co.'s Works, Mansfield Valley, Pa. 1876–78, Assistant Supt. Orinoco Exploring and Mining Co., at their Gold Mines in Venezuela. 1878–79, Supt. of the same. 1879–81, Examining Mines in Colorado, Utah, Nevada and California, for New York Investors. 1881–85, Supt. St. Helena Gold Mines, Sonora, Mexico. 1885, opened office in New York as Consulting Engineer, and since then has been engaged as Consulting Mining and Metallurgical Engineer, in Peru,

Republic of Colombia, Dutch and British Guiana, Mexico, British Columbia, Ontario, New Brunswick, and the United States.

ORMSBEE, JAMES JACKSON, E.M., ... 1886.
Superintendent Poplar Creek Div. Tenn. Coal, Iron & R. R. Co., Tracy City, Tennessee.

1886–91, Mining Engineer of Tracy City Division of Tennessee Coal, Iron and Railroad Co. 1891–92, Superintendent, Thomas Coal Mines, of Tennessee Coal, Iron and Railroad Co., Whitwell, Tenn. 1892–94, Engineer and Superintendent Sequachee Valley Coal and Coke Co. 1894, Superintendent Poplar Creek Div. Tenn. Coal, Iron and Railroad Co.

OSTERBERG, MAX, E.E., ... 1894.
232 E. Sixty-second Street, New York City.

After graduation I was appointed editor of the *Proceedings* of the Chicago Elec. Congress. At the same time I did practical shop work in a dynamo factory. On October 1st was appointed Associate editor of *Electric Power*. October 16th became Instructor at the National School of Electricity. November 1st started a course of lectures in Electric Engineering at the Y. M. C. A. Re-entered college to pursue post-graduate studies.

OSTERHELD, THEODORE W., E.M., ... 1886.
Chief Engineer, Corhuila and Zacetecas R.R., Gomez Farias, Corhuila, Mexico.

Assistant Superintendent of Blast-furnaces, P. S. Co., 1886–87. General Foundry Practice, Worthington P. Works, 1887–88. Owner of Foundry and General Iron Works, 1888–89. Vice-President, Pendleton Mining Co., and Consulting Engineer, 1889, '90, '91, and General Consulting Engineer, Iron and Coal Specialty, and Metallurgist of Iron and Finished Manufacturing. Interval of 1880–91, of the months December to May, Superintending Construction of Rolling Mill, Southwest Virginia. Specialty, Coal and Iron of the Virginias. President of the Southern Reducing Co., Experts, Chemists and Mining Engineers.

OWEN, FREDERICK NASH, E.M., ... 1878.
Civil and Sanitary Engineer, 58 W. Ninety-first Street, New York City.

P.

PAGE, GEORGE STEPHEN, E.M., ... 1885.
Care of Park Bros. & Co., Limited, Pittsburgh, Pa.

1885–86, Assistant Chemist Edgar Thomson Steel Works. From July 1886 to date, Manager of Steel Works with Park Bro. & Co., Ltd. Specialty: Manufacture of Open-Hearth and Crucible Steel.

PAGE, WILLIAM STEVENS, E.M., ... 1882.
Aqueduct Commission, Sing Sing, N. Y.

PAINTER, CHARLES ALBERT, E.M., ... 1884.
J. Painter & Sons, Pittsburgh, Pa., and 208 Western Avenue Allegheny City, Pa.

PAINTER, GEORGE EDWARDS, PH.B., ... 1883.
J. Painter & Sons Co., Pittsburgh, Pa., and 210 Western Avenue, Allegheny City, Pa.

PARKER, ANDREW MCCLEAN, E.M., ... 1880.
Acting 1st Assistant Engineer, Dept. of Docks, Pier A, and 35 W. One Hundred and Nineteenth Street, New York City.

PARKER, HERSCHEL CLIFFORD, PH.B., ... 1890.
Dept. of Physics, Columbia College, New York City, and 21 Ft. Greene Place, Brooklyn, N. Y.

1890–91, Fellow in Physics, Assistant Instructor, Course in Physical Measurements. 1891–93, Assistant. 1893–95, Tutor in Physics.

PARKER, RICHARD ALEXANDER, C.E., ... 1878.
Consulting Mining Engineers, 403 Lyceum Bldg., Duluth, Minn., and East Olive Street, Marquette, Michigan.

1878–79, Assistant Superintendent, Montezuma Silver Mining Co., Montezuma, Colo. 1880–81, Surveyor at Georgetown. 1881–82, Chief Draughtsman, Mexican Natl. Cons. Co., Laredo, Texas. 1883–84, Examining Mines in Colorado, Utah and Idaho mainly 1885–86, Superintendent, Atlanta Hill Gold Co. Also Superintendent of the Big Lode (Gold) Co., Atlanta, Alturas Co., Idaho. 1887 to date, Resident Manager and Agent for Samson Iron Co., Imperial Iron Co., and Barasa Iron Co. Also Consulting Mining Engineer. Specialties, Gold and Silver Mining and Milling, and Iron-ores. Manager of Steel Works.

PARKS, JOHN RANDOLPH, E.M., ... 1880.
Helena, Mont.

Consulting Mining Engineer.

PARRAGA, CHARLES FREDERICK, C.E. (Life Member), . 1883.
58 William Street, and 145 W. Ninety-seventh Street, New York City.

1883–84, Inspector of Construction of Bridges and Railroad Material in Europe. 1884–86, Railroad Engineer in Colombia, S. A. 1887 to date, General Expert Business. 1891, Delegate from Colombia to the Inter-Continental Railway Commission at Washington, D. C.

PARROT, EDWARD MOORE, E.M., ... 1870.
Ontario, Wayne County, N. Y.

PARSONS, HENRY, C.E., ... 1888.
Vice-president City and Suburban Ry., Savannah, Ga., and 1033 Madison Avenue, New York City.

PARSONS, WILLIAM BARCLAY, A.B., C.E., . . . 1882.
22 William Street, and 51 East Fifty-third Street, New York City.

Previous to graduation served as Assistant Engineer Arnot and Pine Creek Railroad and Blossburg Coal Mine. After graduation entered Maintenance of Way Department of the New York, Lake Erie and Western Railroad. Resigned in 1885 and commenced practice as Consulting Engineer, New York, as such have had charge of much heavy engineering construction. At present Chief Engineer Rapid Transit Commission, New York City.

PAYNE, CLARENCE QUINTARD, E.M., ... 1882.
President Payne Separator Co., 136 Liberty St., New York City, and Stamford, Conn.

PEARIS, CHARLES FOWLER, E.M., ... 1884.
Box 374, Helena, Mont.

PECK, STAUNTON BLOODGOOD, C.E., M.E., . . . 1886.
Link Belt Machinery Co., Thirty-ninth Street and Stewart Avenue, Chicago, Ill., and 111 East Thirty-fourth Street, New York City.

One and a half years Mechanical Engineer, Burr & Dodge, Philadelphia. Two years Assistant Chief Engineer Link Belt Engineering Company, Philadelphia. Since

1888. Assistant Chief Engineer Dodge Coal Storage Company. Since 1890 and at present, Chief Engineer Link Belt Machinery Company, Chicago. Specialty, handling materials in bulk or package and power transmissions.

PEELE, ROBERT, JR., E.M., ... 1883.
"The Monterey," One Hundred and Fourteenth Street, and Morning Side Park, New York City.

1883, Assayer, Designolle Reduction Works, Charlotte, N. Carolina. 1883-84, Assayer and Assistant Supt. Silver-King Mining and Milling Co., Montezuma. Colorado. 1884-86, Foreman, Dry-crushing and Amalgamating Silver-mill, Silver-King Mining Co., Pinal, Arizona. 1886, went to England to examine systems of Sewage-disposal used in inland towns. 1887, Professional work as Assistant, in New York and Arizona. 1888, Examining gold-mines in Republic of Colombia, S. A. Supt. Mudsill Mining Co., Ltd., Fairplay, Colorado. Examinations and Ore-testing on Copper and Tin Properties, New Mexico and North Carolina. 1889, Examining Gold-placers, Dutch Guiana, South America. 1889-90. Supt. Oregon Gold-mining Co., Cornucopia, Oregon. 1890-92, Examining Silver-, Tin-, and Gold-mines in Peru, Bolivia, and Republic of Colombia, S. A., for the Peruvian Exploration Syndicate, Ltd., London, and Lima, Peru. 1892, Adjunct Prof. of Mining, School of Mines, Columbia College.

PELLEW, CHARLES ERNEST, E.M., ... 1884.
College Physicians and Surgeons, 437 West Fifty-ninth Street, and 68 East Fifty-fourth Street, New York City.

1884-85, studied chemistry at Lehigh University and Bethlehem Steel Works. 1885-87, studied chemistry, physics, microscopy and bacteria at School of Mines and at College Physicians and Surgeons. Private Assistant to Professor Chandler. 1887 to date, Instructor and, later, Demonstrator in Physics and Chemistry at College Physicians and Surgeons. Hon. Fellow in Applied Chemistry, School of Mines. Also in general chemical practice with Professor Chandler (as partner). Specialty, chemical and other expert work, including medical and sanitary questions, *e.g.*, toxicology. Also as patent expert in chemical and physical subjects.

PENNINGTON, JOSEPH POPE, A.M. (Associate), . . . 1868.
Morristown, N. J.

Assistant Engineer E. T. V. & G. R.R. 1881-83, Engineer Tombstone Mill and Mining Company. 1883-84, 1885 *et seq.*, railroad construction with general contractors. Assistant Secretary, Louisville, St. Louis and Texas Railway. Resigned August, 1893. Previous responsibilities in connection with life insurance interests.

PERKINS, THOMAS SLADE, PH.B., ... 1888.
Ninth Street and Gowanus Canal, South Brooklyn, and 39 Garden Place, Brooklyn, N. Y.

1889 to date, New York Tartar Company.

PIERCE, FREDERICK EMERY, C.E., ... 1892.
Superintendent of Works Newark Gas Light Co., Newark, N. J.

Learner in Bessemer Mill, Maryland Steel Co., Sparrow's Pt., Maryland. Draughtsman, New Jersey Steel and Iron Co., Cooper, Hewitt & Co., New York City. Superintendent of Works Newark Gas Light Co., Newark, N. J.

PIEZ, CHARLES, E.M., ... 1889.
Chief Engineer Link Belt Engineering Co., Nicetown, Philadelphia, Pa.

1889-91, Draftsman with the L. B. E. Co. 1891-92, Assistant Chief Engineer L. B. E. Co. Since 1892 Chief Engineer of the L. B. E. Co., and the Dodge Coal Storage Company, Philadelphia.

PISTOR, WILLIAM, E.M., ... 1868.
Architect, No. 1 Madison Avenue, New York City.

PITKIN, LUCIUS, A.B., PH.B., ... 1881.
138 Pearl Street, New York City.

1881–85, Chemist to Laurel Hill Chemical Works, of Nichols Chemical Company, Heavy chemicals, especially sulphuric acid. 1885 to date, Analytical and consulting Chemist, at above address. Specialty, in consulting. Manufacture of acids and heavy chemicals, treatment of pyrites and copper smelting. Analytical work. General, but special experience in argentiferous and auriferous copper-ores and products. Microscopical and experimental investigations.

POLLEDO, YSIDORO YGNACIO, E.M., ... 1885.
Apartado 167, Matanzas, Cuba.

1885, Assistant Engineer, Survey for Water-Works for city of Santiago de Cuba, 1886–89, Assistant Engineer and Principal Assistant Engineer in charge of track and structures, Cárdenas and Júcuro R.R., Cárdenas, 1889–90; Manager of Santa Barbara Sugar Plantation, Baró. 1894–94, General Manager Cárdenas Sugar Refinery, Cárdenas.

PORTER, H. HOBART, JR., E.M., ... 1886.
Westinghouse Electric and Mfg. Co., 120 Broadway, New York City, and Lawrence, L. I., N. Y.

1886–87, Fellow in Geology, School of Mines, Columbia College. 1887–88, Surveyor and Assayer Mexican Ore Company, Sierra Mojada, Mexico. 1888–89, Assistant Mining Engineer Batopilas Mining Company, Batopilas, Mexico. 1889–90, Surveyor and Assayer, Duquesne Mining Company; Assistant Superintendent, Ray & Poorman mine examinations, same company; Assistant Superintendent Sierrita County, Arizona, same company. 1890–91, Engineer with C. W. Hunt Company. 1891 to date, Westinghouse Electric and Mfg. Co.

PORTER, JOHN BONSALL, E.M., PH.D., ... 1882.
Chemical Engineer Proctor-Gamble Co., Ivorydale, Ohio, and Glendale, Hamilton County, Ohio.

Assistant Engineer and Expert in tests of metals for various railways and corporations. Lecturer on Mechanical Engineering and Metallurgy in University of Cincinnati for some years. At present and for several years past, Engineer Maintenance of way, C. H. & D. R.R. system. Headquarters, Cincinnati, O. Chemical Engineer Proctor-Gamble Co., Ivorydale, Ohio.

POST, ABRAM SKIDMORE, C.E., ... 1884.
173 Madison Avenue, N. Y. City.

POST, ALBERTSON VAN ZO, C.E., ... 1889.
45 Wall Street, and 4 East Sixty-second Street, New York City.

1889–90, Division Engineer, construction, Baltimore and Eastern Shore Railroad. 1891 to date, with the Railroad Equipment Company, of 45 Wall Street, New York City.

POTTER, WILLIAM BLEECKER, A.B., E.M., . . . 1869.
Consulting Mining Engineer, 1225–1227 Spruce St., St. Louis, Mo.

Professor Metallurgy and Mineralogy, Washington University, St. Louis, Mo., to 1893.

POWELL, FREDERICK, A.B., E.M., ... 1883.
Charlotte Mineral and Mining Co., Charlotte, N. C.

1883–84, Mechanical Draughtsman and Engineer. 1885, Assayer at Duluth, Examination and Reports on Mineral Deposits in northeastern Minnesota and Canada, Assayer and Manager for Sentinel Gold Mining Co. of Minneapolis and Colorado. 1886 to 1888 Superintendent and Manager in Colorado for Denbigh Mining Co. of New York. 1888-92, Miscellaneous Surveying. 1893, Engineer for Charlotte Mineral and Mining Co., Charlotte, N. C. Examining and Reporting on Mines in North Carolina. June, 1894, to date, Mining Engineer, Charlotte, N. C.

POWERS, LEWIS J., JR., E.M., ... 1884.
Connecticut River Paper Company, Holyoke, and 4 Mattoon Street, Springfield, Mass.

1885, Superintendent Vermont Construction Company, St. Albans, Vt. 1886, Superintendent Standard Pulp Company, Springfield, Mass. 1887–88, Assistant Superintendent Union Paper Manufacturing Company, Holyoke, Mass. 1888 to date, Agent Connecticut River Paper Company, Holyoke, Mass.

PRESTON, WILLIAM EVAN, C.E., ... 1889.
980 Trinity Avenue, New York City.

1889 to date, submarine blasting and dredging for U. S. harbor work with grapple, divers and centrifugal pump.

PROVOST, ANDREW JACKSON, JR., C.E., ... 1889.
Municipal Building, and 403 Washington Avenue, Brooklyn, N. Y.

1889 to date, Assistant Engineer in Sewage Construction, Department City Works, Brooklyn, N. Y.

R.

RANDOLPH, JOHN COOPER F., A.B., A.M., E.M., . . 1869.
Consulting Mining Engineer, Mills Building, 15 Broad and 35 Wall Street, New York City, and 18 Elm Street, Morristown, N. J.

Graduated: Princeton, 1866, and School of Mines, New York City, 1869. 1869–71, in Germany, service of U. S. Govt. 1874, in service Japanese Govt. 1884, in Central China for a Chinese Syndicate. 1887, Resident Manager of La Plata Mines, Republic of Colombia, S. A.; National Commissioner of Mines for Tolima, Republic of Colombia, S. A. 1890, Resident Manager in Borneo of Borneo Diamond Exploration Syndicate, Ltd. For 23 years actively engaged in Professional Work in the United States, Mexico, etc. At different times Member of Council and Vice-president of the American Institute of Mining Engineers. 1891, sick. 1892, all the year in Mexico and Colorado. 1893, in Sonora and Virginia, and various other mining matters in different parts of the country.

RANDOLPH, JAMES FITZ, B.S., E.M., ... 1876.
Communipaw Coal Co., 111 Broadway, New York City.

RAYMOND, ROBERT MATTHEW, A.B., E.M., . . . 1889.
Harqua Hala Gold Mining Co., Harqua Hala, Ariz.

1880–82, Assistant Assayer, State of Maine Assay Office, Portland, Me. 1882–86, Assayer and Assistant Superintendent, Haile Gold Mine, S. C. 1886–89, School of Mines. 1889–90, Assayer and afterwards Assistant Superintendent, Montana Smelting Co., Great Falls, Mont. 1891, Superintendent, The Diamond Mining Co., Neihart, Mont. 1894, General Manager Harqua Hala Gold Mining Co., Harqua Hala, Ariz.

RAYNOR, RUSSELL, PH.B., ... 1889.
Criminal Court Building, and 114 E. Forty-fifth St., New York City.
Sept., 1889, to Aug., 1891, Chemist, with Martin Kalbfleisch Sons Co. Sept., 1891, to April, 1892, Assistant Chemist, Barber Asphalt Co. May, 1892, to date, Assistant Chemist New York Health Department.

RECKHART, DANIEL WILLIAM, E.M. (Life Member), . 1884.
Reckhardt & Heckelman, Assayers, Box 88, El Paso, Texas.

RECKHART, GEORGE FREDERICK, C.E., ... 1892.
Manager, The Furners & Lewis Co., Apartado No. 23, Pachuca, Estado de Hidalgo, Mexico.
Member of "The Southwestern Mining Association" (Incorporated). Surveyor and Assayer for Cia Minera La Aventurera, Sabinal, Estado de Chihuahua, Mexico, since September, 1894. From February, 1894, to August, 1894, was on Engineering Staff of South Shore Railroad Co., Ltd., of Nova Scotia, Canada.

REED, SYLVANUS ALBERT, A.B., A.M., E.M., PH.D., . 1877.
Manager Tariff Association of New York (Fire Underwriters), 32 Nassau Street, New York City.
1878, Secretary to Assistant Commissioner General, Paris Exposition. 1879, Lectured on Chemistry. Reported on Mines in Colorado. 1880–84, Superintendent and part Proprietor, Sampling and Concentration Works in Colorado, and Reported on Mines there and in Idaho and in the South. 1886, Consulting Practice in New York, Patent Expert work and on Dredging in New York Harbor. 1886–91, Superintendent Inspection Department of Fire Insurance Co. (Commonwealth, of New York). 1893, Expert for New Insurance Rating, Mercantile Section of Boston. May, 1893, appointed Manager Western Factory Insurance Association. Special Agent Western Department of Continental Insurance Co. 1894, Manager Tariff Association Fire Underwriters, New York City.

REES, JOHN KROM, A.B., A.M., E.M. (Life Member), . 1875.
Professor of Astronomy and Director of Observatory, Columbia College, and 1 W. Seventy-second St., New York City.
A. B., Columbia College, 1872. Fellow in Science, 1872–75. A.M., 1875. E.M., 1875. Assistant in Mathematics, School of Mines, 1873–76. Professor of Mathematics and Astronomy, Washington University, St. Louis, Mo., 1876–81. Director of the Observatory, Columbia College, 1881. Instructor in Geodesy and Practical Astronomy, Columbia College, 1881–82. Professor of Astronomy, 1892. Chairman Board of Editors, SCHOOL OF MINES QUARTERLY, 1883–90. Vice-President New York Mathematical Society, 1891. Chairman of Section on Astronomy and Physics of New York Academy of Sciences, 1891. Secretary of American Metrological Society, 1882. Fellow of Royal Astronomical Society of London, 1892. Member of the Astronomische Gesellschaft, 1893. President of New York Academy of Sciences, 1894–95.

RENAULT, GEORGE, C.E., ... 1883.
61 Irving Place, New York City.

RESTREPO, CAMILO CLAUDIO, E.M., C.E., . . . 1887.
Medellin, Republic of Colombia.

RHODES, FRANCIS BELL FORSYTH, E.M., . . . 1874.
National S. & R. Co., South Chicago, Ill., and Quebec, Canada.
May, 1875, to December, 1876, Surveying Corps, Coxe Bros., Drifton, Pa. January,

1877, to May, 1878, Assistant Superintendent, South American Mining Co., Venezuela. November, 1878, to June, 1879, Working at Lead Mine, Canada. October, 1879, to April, 1880, Laborer, Ontario Mill, Park City, Utah. April, 1880, to July, 1881, Assistant Superintendent, Minge Furnace Co., Utah. August, 1881, to January, 1882, Assistant Superintendent St. Helena Mine, Sonora, Mexico. January, 1882, to April, 1883, Assistant Superintendent, Tombstone M. and M. Co., Arizona. May, 1883, to December, 1883, Superintendent, Ramsham Smelting Furnace, Idaho. January, 1884, to May, 1885, Assistant Superintendent, Minge Furnace Co., Utah. June 1885, to December, 1885, Foreman of Blast-furnace Department, Kansas City S. and R. Co. October, 1886, to December, 1889, Superintendent, Chicago Works, Chicago and Aurora S. and R. Co. January, 1890, to date, Superintendent National S. and R. Co., South Chicago.

RHODES, ROBERT DUNN, E.M., ... 1879.

Supt. Arkansas Valley Smelting Works, Leadville, Col., and Box 726, Quebec, Canada.

1879–80, Foreman, Germania Smelting Co., Salt Lake City. 1880–82, Night Foreman, Ontario Silver Mining Co., Park City, Utah. 1882–83, Superintendent, Tombstone M. and M. Co. Reduction Works, Charleston. 1883–84, Mill Foreman, St. Helena Gold and Silver Mine, Sonora. 1884–85, Assistant Superintendent, Billing Smelter, New Mexico. 1885–86, Assistant Superintendent, Viola M. and S. Co., Idaho. 1887–88, Assistant Superintendent, Anglo-Mexican Mining Co., Yedras, Mexico. 1889–91, General Superintendent, Duquesne M. and R. Co., and Sierrita County, Arizona. 1891–92, Engineer Fraser & Chalmers, City of Mexico. 1892–94, Supt. as above.

RICE, GEORGE SAMUEL, JR., E.M., ... 1887.

119 S. Market Street, and 432 N. Court Street, Ottumwa, Iowa.

1887, Assistant Field Engineer, Colorada & Utah Railway. 1888–89, Assistant Mining Engineer of Colorado Fuel Co. 1890 to date, Mining Engineer of Whitebreast Fuel Co.

RICH, JACOB MONROE, E.M., C.E. (Life Member), . . 1883.

50 W. Thirty-eighth Street, New York City.

Pursuing further studies since graduation.

RICHARDSON, JOHN CLARENCE, E.M., C.E., . . . 1883.

Address unknown.

RICKETTS, PIERRE DEPEYSTER, E.M., PH.D., . . . 1871.

Professor, Analytical Chemistry, Columbia College, School of Mines, and 115 E. Seventy-ninth Street, New York City.

1868, Assistant, General Chemistry, Columbia College. 1871–72, Assistant in Mineralogy and Metallurgy, School of Mines. 1872–75, Assistant in Assaying, School of Mines. 1875–86, Instructor in Assaying, School of Mines. 1886 to date, Professor of Assaying, School of Mines. Since graduation also engaged in general Metallurgical, Chemical and Mining Engineering work.

RIDSDALE, THOMAS WEDDLE, E.M., ... 1883.

Ridsdale & Lewis, 39–41 Cortlandt Street, New York City.

Assistant Superintendent of the Ruby Durango Mine, and Wilder-Macdonald Concentrating Mill to 1884. Superintendent of the Wilder-Macdonald Mill, 1884. From 1888 with the Worthington Pumping Engine Co. From June, 1889, as Secretary of the Company.

RIES, HENRICH, PH.B., ... 1892.

Mineralogical Department, School of Mines, Columbia College, and 28 W. 128th Street, New York City.

Summer of 1891 and 1892, on New York Geological Survey. October, 1892, to August 1st, 1893, Assistant Director, New York Scientific Exhibit at World's Fair. July 1st, 1893, to July 1st, 1894, Fellow in Mineralogy, Columbia College.

ROESER, FREDERICK, B.S., E.M., ... 1894.
240 West 130th Street, New York City.

ROGERS, OSCAR LEGARÉ, PH.B. (Arch.), ... 1889.
27 West Eighty-second Street, New York City.
1889–92, in Europe. 1893, Architect. 1894, In Europe.

ROLKER, CHARLES M., E.M. (Life Member), . . . 1875.
Mining and Financial Trust Syndicate, Limited, No. 6 Draper's Gardens, London, E. C., England.
1868–70, At Royal School of Mines, Clausthal, Germany. 1871–72, Working practically in Iron Mines of Hibernia and Mt. Pleasant, N. J., Wisconsin Lead Mines and Iron Mines of Lake Superior. 1872–75, At School of Mines, Columbia College. 1876, Assayer at Allouez Copper-dressing Works, Lake Superior. 1877, Mining Engineer to the Mariposa Land and Mining Co., Mariposa Co., Cal. (Gold). 1878, Superintendent, Brooklyn Company, Washoe Co., Nevada (Base Metal). 1879, Superintendent. Stormont Silver Co., Silver Reef (Silver). 1880–82, General Manager, Chrysolite S. Mg. Co., Leadville, Colo. (Lead Carbonates). Since then to date, in General Consulting Practice as Mining Engineer and Metallurgist, Examining Mines, Mills and Placers, in the United States, Old Mexico, Central America, South America and East Indies. Specialty, Precious and Base Metals other than Iron. 1891–92, Cons. Engr. to the British South African Company in its sphere south of Zambesi. 1894, Practicing, Consulting Mining Engineer.

ROOD, ROLAND GOUVERNEUR, PH.B., ... 1884.
Care Prof. O. N. Rood, Columbia College, New York City.

ROSENTHAL, ALBERT, C.E., ... 1892.
158 East Seventy-ninth Street, New York City.

ROWLAND, CHARLES BRADLEY, C.E., ... 1884.
Continental Iron Works, Greenpoint, Brooklyn, N. Y., and 329 Madison Avenue, New York City.

ROWLAND, GEORGE, C.E., ... 1887.
Continental Iron Works, Greenpoint, Brooklyn, N. Y., and 329 Madison Avenue, New York City.

RUPP, PHILIP, PH.B., M.D., ... 1884.
84 Second Avenue, New York City.
1884–87, Student in Medicine, College of Physicians and Surgeons, N. Y. 1887–88, House Physician and House Surgeon, St. Francis Hospital, N. Y. 1888 to date, Practicing Physician.

RUTTMANN, FERDINAND, JR., E.M., ... 1880.
35 Broadway, New York City.

RYON, AUGUSTUS MEADER, E.M., ... 1886.
Prof. Engineering, College of Agriculture and Mechanic Arts, Bozeman, Montana.
1886–87, Assistant Engineer on New London Water Works. Assistant in Metallurgy, School of Mines, Columbia College. 1887–88, Assistant to F. N. Owen, Civil and Sanitary Engineer, New York City. 1888–91, Professor of Engineering and Min-

ing, School of Mines, College of Montana, Deer Lodge, Mont. 1892 to date. President and Professor of Engineering, Montana College of Agriculture and Mechanic Arts, Bozeman, Montana. 1894, Irrigation Engineer for Agricultural Experiment Station.

S.

SAGE, EDWARD EUGENE, C.E. (Life Member), . . . 1877.
United States Assay Office, 30 Wall Street, New York City, and 77 Hillside Avenue. Orange, N. J.

I have been connected with this office since February, 1879, and have consequently no outside experience except in electricity, being President of the Essex County Electric Co., of Orange, N. J., and in Analytical Chemistry.

SANDS, FERDINAND, A.B., PH.B., ... 1882.
Drugs and Assaying Supplies, Box 1172, Butte, Mont.

SCHERMERHORN, FREDERICK AUGUSTUS, E.M. (Life Member), ... 1868.
41 Liberty Street, and 61 University Place, New York City.

SCHIEFFELIN, WILLIAM JAY, PH.B., PH.D. (Munich), . 1887.
Schieffelin & Co., 170 William Street, and 35 West Fifty-seventh St., New York City.

SCHNEIDER, ALBERT FRANCIS, E.M., C.E. (Life Member), 1876.
Care of Great Falls Smelting Co., Monterey, Mexico.

1876–1877, In Europe visiting Smelting and Dressing Works. 1878, Chemist and Assayer Germania S. and R. Co., Salt Lake City, Utah. 1879, Foreman, Assistant and Superintendent Germania S. and R. Co., Salt Lake City, Utah. 1880–'83, Superintendent Germania S. and R. Co., Salt Lake City, Utah. 1883–'85, Superintendent G. Billing Smelting Works, Socorro, N. M. 1885–'87, Superintendent Kansas City S. and R. Co., Argentine, Kansas. 1887, Connected with the Rio Grande S. Co., Socorro, N. M. 1887 to 1893, General Manager St. Louis S. and R. Co., St. Louis, Mo. Superintendent Great National Smelting Co., Monterey, Mexico.

SCHROEDER, J. LANGDON, C.E., ... 1889.
Member of firm of Parrish & Schroeder, Architects, 1 Madison Ave., and 27 E. Thirty-first Street, New York City.

July, 1890, to January, 1894, with Renwick, Aspenwall & Renwick, New York City, as Architectural Draughtsman.

SCHROTER, GEORGE AUSTIN, E.M., ... 1893.
Box 877 and 1525 Blake Street, Denver, Colo.

Superintendent Keystone and Manager Logan Group Mines, Colorado. Chemist Denver White Lead Works, February–August, 1894.

SCHUMANN, CHARLES HENRY, C.E., ... 1888.
Small & Schumann, 265 Broadway, New York City, and 349 Sixth Avenue, Brooklyn, N. Y.

1888, May, 1890, Assistant Engineer Chesapeake and Ohio Railway Co., Cincinnati, charge of Real Estate, Right of Way and Track and Construction work. May to August, 1890, Assistant Engineer to H. Alber, C. E., Birmingham, Ala., General Engineering. August, 1890, to March, 1891, Assistant Engineer Chesapeake and Ohio Railway Co., charge of subdivision of Town of West Clifton Forge, Va., and Right of Way on line of road. 1892-93, Assistant Engineer Long Island R. R., and Engineer for

Ferris & Richards, Contractors for Railroads and Waterworks, at 98 Hudson St., Jersey City, N. J. 1893–94, with J. James R. Croes., C.E., Waterworks Supply and Sewerage. 1894, Private practice as Small & Schumann, Architects and Civil Engineers.

SELIGMAN, JOSEPH GUY, E.M., ... 1887.
Mining Superintendent, and 506 W. 143d Street, New York City.

SELDNER, RUDOLPH, PH.B., ... 1894.
Adelphi Academy and 217 Jefferson Avenue, Brooklyn, N. Y.

SELF, E. D., E.M., ... 1894.
South Orange, N. J.

Located at Nogales, Arizona, as Consulting Engineer. Making examination of mining property.

SHARE, WILLIAM WALDEMAR, PH.B., PH.D., . . . 1881.
Adelphi Academy, and 331 McDonough Street, Brooklyn, N. Y.

1881, Superintendent Columbia Chemical Works, Brooklyn, N. Y. 1881 to 1888, Assistant Physics, Columbia College. 1888, Consulting Electrician, Department of Public Parks, Brooklyn, N. Y. 1889 to date, Professor of Chemistry, Adelphi Academy, Brooklyn, N. Y.

SHERMAN, FRANK DEMPSTER, PH.B., ... 1884.
Adjunct Professor of Architecture, School of Mines, Columbia College, and 71 E. Eighty-seventh Street, New York City.

SHRIVER, HENRY TOWER, PH.B., ... 1888.
T. Shriver & Co., 333 E. Fifty-sixth Street, and 686 Park Avenue, New York City.

In Iron Foundry and Works, as above, since graduation.

SIMONDS, FRANCIS MAY, E.M., PH.D., ... 1887.
Assistant in Assaying, Columbia College, School of Mines, and 147 E. Thirty-fourth Street, New York City.

SINGER, GEORGE, JR., E.M., ... 1880.
111 Fourth Avenue, Pittsburgh, Pa.

SINGER, GEORGE HARTON, E.M., ... 1880.
Singer, Nimick & Co., and 17 Park Street, Allegheny, Pa.

SKINNER, ELMER, C.E., ... 1891.
227 Cumberland Street, Brooklyn, N. Y.

SLACK, CHARLES GODDARD, E.M., ... 1884.
328 Fourth Street, Marietta, Ohio.

SLADE, RICHMOND EDWARD, PH.B., ... 1887.
White Plains, N. Y.

1887, Assistant Superintendent United Gas Improvement Co., Yonkers, N. Y., Plants. 1888, Superintendent Gas Department, Asheville (N. C.), Light and Power Co. 1889, Superintendent Gas and Electric Plants, Citizens' Gas Light Co., Jackson, Tenn. December, 1889, to date, Secretary, Superintendent and Trustee Citizens' Gas and Electric Co., White Plains, N. Y.

SMITH, AUGUSTUS, A.B., C.E., ... 1889.
39 Cortland Street, and 460 W. Forty-fourth Street, New York City.

Summer of 1886, Land Surveying (in charge of Party). July to November, 1889, Draughtsman, Link Belt Engineering Co., Nicetown, Phila. November, 1889-91, Chief

1886, on railway surveys in Minnesota and Wisconsin with C. B. & N. R.R. Co. 1887–89, Fellow in Engineering and Assistant in Summer School of Surveying, School of Mines, Columbia College. 1889–90, making surveys and superintending construction at the Hudson River State Hospital, Poughkeepsie, N. Y. 1890, on surveys in the West Indies. 1893, in general practice.

SUTER, GEORGE AUGUSTUS, E.M., ... 1883.

G. A. Suter & Co., Engineers and Contractors, 139 South Fifth Avenue, New York City, and 206 Marcy Avenue, Brooklyn, New York.

1884–92, Engineer, Baker, Smith & Co. 1892 to date, as above.

SWAIN, ALFRED ERNEST, E.M., ... 1881.

Supt. Trinidad Mining Co., Copala (via Mazatlan, Sinaloa, Mexico), and 902 Prospect Street, Cleveland, O.

1881–84, railroad work in Mexico. 1886–88, City Engineer's Department, Kansas City, Mo., in charge of sewer work. 1889–91, mining work in Mexico. 1891, Supt. San Buenaventura Mining Company, Santa Lucia, Sinaloa, Mexico, via Mazatlan and Panna. 1891–93, Supt. Trinidad Mining Co.

T.

TAINTOR, WM. NOYES, PH.B., ... 1894.

60 West Forty-eighth Street, New York City.

August, 1894, to September, 1894. Levelman, Metropolitan Traction Co. September, 1894, to date, Transitman, Ramapo Water Co.

TAYLOR, JOSEPH B., E.M., ... 1888.

58 William Street, Room 7, New York City.

TEMPLE, SETH JUSTICE, PH.B., ... 1892.

Care Sebastin Reali, Rome, Italy.

Instructor in Architectural Drawing Art Schools of the Metropolitan Museum of Art, Fifth Ave. and Thirty-Second Street, New York City.

TERHUNE, RICHARD HENRY, E.M., ... 1870.

San Jose, Cal.

1870, Assistant to late J. W. Foster, geology of coal fields, Indiana. 1871, Griswold Steel Works, draughting, blowing steel, etc. 1872–77, Joliet Steel Company, draughting, inspecting steel rails and exploration of Callaway County, Missouri, for coal and iron. 1877–80, Superintendent and Assistant Superintendent Smelting Works in Utah. 1880–93, General Superintendent Hanauer Smelting Works, Utah. Specialty, construction and operation of lead smelting works. Resigned above position September, 1893. 1894, Examining and Reporting on Mines and Works.

THACHER, ARTHUR, C.E., E.M., ... 1877.

4109 Washington Avenue, St. Louis, Mo.

1878–79, with Progreso Mining Company, Trimfo, Lower California, Mexico. 1879–83, Southern Arizona and Northern Mexico Mining and Milling. 1883–87, office in New York. Examining and reporting on mines and mills. 1887 to date, with Professor W. B. Potter, at St. Louis Sampling and Testing Works and Washington University. Lecturing on Metallurgy. Testing ores, etc. Examining and reporting on mines and mills. Superintendent Central Lead Co.

THOMAS, FREDERICK MAYHEW, E.M., ... 1885.

20 City Hall, Syracuse, N. Y., and Box 204, Skaneateles, N. Y.

Leveller (Instrument man, etc.), on New York State Canals, from September, 1887, to November, 1889 (position resigned). Transitman and leveller on preliminary

railroad survey in Schoharie County in spring of 1890. Transitman and leveller on Syracuse water works during the winter of 1890–91.

THOMPSON, HENRY CLARK, C.E., ... 1886.
Lorillard Place, and One Hundred and Eighty-seventh and One Hundred and Eighty-eighth Streets, New York City.

TIBBALS, GEORGE ATWATER, C.E., ... 1883.
Continental Iron Works, and 148 Milton Street, Brooklyn, N. Y.
1883 to date, as above.

TIBBALS, SAMUEL GAYLORD, C.E., ... 1884.
Continental Iron Works, and 148 Milton Street, Brooklyn, N. Y.
1884 to date, as above.

TILDEN, GEORGE CYRUS, C.E., ... 1876.
State School of Mines, Golden, Colo.
1876-80, City Surveyor, Brooklyn, N. Y. 1880-81, Superintendent Dunderberg Mining Company, Georgetown, Colo. 1881–82, Chemist and Assayer, Denver, Colo. 1882 to date, Professor Analytical Chemistry State School of Mines, Golden, Colo. 1881 to date, Consulting Practice as Mining Engineer. Specialty, Analytical Chemistry and Assaying.

TITUS, WARREN HARRIOTT, E.M., ... 1885.
Sanitary Engineer, Department of Buildings, New York City, 220 Fourth Avenue and 80 E. Washington Square, New York City, and Whitestone, N. Y.

TONNELÉ, THEODORE, PH.B., ... 1880.
Care of Wm. Dewees Wood Co., McKeesport, Allegheny Co., Pa.
In charge of Refining and Steel Departments of the Wm. Dewees Wood Company.

TORREY, CHARLES HERBERT, PH.B., ... 1880.
Pasadena, Cal.
1880–83, Assistant in Qualitative Laboratory, School of Mines. 1883–85, teaching in New York Institute for Improved Instruction to Deaf Mutes, New York City. 1885–87, in the employ of the DuBois Manufacturing Company of New York, in their branch in London. 1887–93, Manager German Branch DuBois Manufacturing Co., at Berlin, Germany.

TOWER, ALBERT EDWARD, E.M., ... 1883.
Poughkeepsie Iron Company, Poughkeepsie, N. Y.

TOWER, FREDERIC WETHERWAX, E.M., ... 1887.
Assistant Examiner, Room 223, Patent Office, and 1400 L St., N. W., Washington, D. C.
1888 to date, as above.

TRAPHAGEN, FRANK WEISS, PH.B., PH.D., . . . 1882.
Chemist in Charge of Chemical Laboratory, Montana College of Agriculture, Bozeman, Mont.
1883–84, Chemist for Williams, Clark & Co., Fertilizers. 1884–87, Instructor in Chemistry and Physics, Staunton Military Academy, Staunton, Va. 1887, Professor of General, Analytical and Applied Chemistry and Assaying in the College of Montana and Montana School of Mines. 1884–87, Analytical and Consulting Chemist, Staunton, Va. 1887, Principal work, fertilizer, iron and steel, clays, etc. Analytical and consulting Chemist and Assayer, Deer Lodge, Mont. Assaying, miscellaneous analysis and legal work. 1890, Assayer for the Champion Consolidated Mining Com-

pany, Deer Lodge, Mont. 1892-93, In charge Montana Mining Exhibit at Columbian Exposition. 1893, Professor Chemistry Montana College of Agriculture and Mech. Arts. 1895, Chemist Montana Agricultural Experiment Station.

TRASK, GEORGE FRANCIS DONNELL, E.M., . . . 1887.
Care Gordon, Grant & Co., Port of Spain, Trinidad, W. I., and New Brighton, Staten Island, N. Y.

1888-90, Apprentice and Machinist, L. & N. Railroad. 1890-91, Draughtsman, L. & N. Railroad, Louisville.

TUSKA, GUSTAVE ROBITSCHER, B.S., M.S., C.E., . . 1891.
School of Mines, Columbia College, 41 East Forty-ninth Street and Santa Margheretta, 1125 Madison Ave., New York City.

1891-92, Civil and Mechanical Engineer Link-Belt Engineering Co., Philadelphia. 1892-93, Bridge Engineer, Long Island Railroad. Assistant Engineer C. N. Y. and W. R.R. in charge of Stony Brook viaduct, 1893. Consulting Engineer Port-au-Prince Ry., Cuba, 1893 to date. Resident Engineer Knoxville, Cumberland Gap and Louisville R. R. Co., in charge of Construction of Louisville Viaduct, 1893. Assistant to Professor of Civil Engineering, Columbia College, 1893. Tutor in Civil Engineering, School of Mines, 1894.

TUTTLE, EDGAR GRANGER, E.M., ... 1881.
520 Summer Street, Newark, N. J.

1881, Assistant Engineer, Tilly Foster Iron Mine, Brewster, N. Y. 1881-82, Division Engineer, Wheeling & Lake Erie R. R., Toledo, O. 1882-83, Assayer and Mining Engineer. Silver City, New Mexico. 1883-85, Division and Office Engineer, Arizona & New Mexico Railroad, Lordsburgh, Arizona. 1885, Constructing Engineer at Mines, Arizona Copper Co., Clifton, Arizona. 1885-89, Mining Engineer, Cambria Iron Co., Johnstown, Pa. 1889, Superintendent Alamo Coal Co. and Coahuila Coal Co., San Felipe, Coahuila, Mexico, or Box 109, Eagle Pass, Texas. July and August, 1894, Special in Deep River Coal Field for Egypt Coal Co., Egypt, N. C. October, 1894, Examinations. 1889 to April, 1894, Superintendent Alamo Coal Co. and Coahuila Coal Co.

TYLER, WALTER LINCOLN, C.E., ... 1887.
116-120 Front Street, and 1314 Pacific Street, Brooklyn, N. Y.

1887, Levelman and Transitman on the Roanoke & Southern Railroad, Va. 1888, With J. A. Latham, C.E., Providence, R. I. 1888-89, With F. N. Owen, E.M., Sanitary Engineer, New York City. 1889 to the present time, With The A. B. See Manufacturing Co., 116-120 Front Street, Brooklyn.

V.

VAIL, LEWIS H., E.E., ... 1894.
Locust Valley, Long Island, N. Y.

VALUE, BEVERLY REID, E.M., ... 1884.
Address unknown.

VANDERPOEL, FRANK, E.M., PH.D., ... 1875.
Chemist, The Celluloid Co., 295 Ferry St., Box 55, and 191 Roseville Avenue, Newark, N. J.

1875-78, Salesman, with E. B. Benjamin. 1878 to date, as above.

VAN ARSDALE, WILLIAM HENRY, A.B., A.M., E.M., . 1868.
Vice-President, Chicago and Aurora Smelting and Refining Co., Chicago, Ill.

VAN BLARCOM, ELBERT CHAMPLIN, C.E., . . . 1876.
Care H. de San Francisco Pachuca, Hidalgo, Mexico.

VAN CORTLANDT, EDWARD NEWENHAM, E.M., . . 1885.
Tuxedo Park, N. Y.

VAN DYCK, EDWIN, PH.B., ... 1888.
1080 Dean Street, Brooklyn, N. Y.

VAN SINDEREN, ALVAN HOWARD, PH.B., . . . 1881.
Attorney and Counselor-at-Law, 15 Broad Street, and 29 Washington Square, New York City.

VAN VOLKENBURGH, EDWARD, JR., C.E., . . . 1888.
Morgan & Bartlet, 41 Wall St., New York City.

VAN WAGENEN, THEODORE FRANCIS, E.M., . . . 1870.
Tellunde, Colo.

1893, President and General Manager of the Deming Ore Co., Deming, Grant Co., New Mexico, 1894, Consulting Mining Engineer, Denver, Colo.

VOLCKENING, GUSTAV JULIUS, JR., MET. ENG., E.M., . 1888.
675 Lafayette Avenue, Brooklyn, N. Y.

VONDY, RUDOLPH HARRISON, E.M., ... 1882.
305 Montgomery St., Jersey City, N. J.

1882–83, Assistant Engineer, Tilly Foster Iron Mine. 1885–92, Chemist Phœnix Iron Works, Phœnixville, Pa. 1892, Supt. Plenty Hort'l and Skylight Works.

VON NARDROFF, ERNEST ROBERT, E.M., . . . 1886.
Instructor of Physics, Barnard College, 343 Madison Avenue, New York City, and 262 Penn Street, Brooklyn, N. Y.

VULTÉ, HERMANN T., PH.B., PH. D., ... 1881.
Assistant in Quantitative Analysis, School of Mines, New York City, and New Rochelle, N. Y.

1881–82, Superintendent Columbia Chemical Works, Brooklyn, N. Y. 1883–91, Assistant Instructor in Analytical Chemistry, School of Mines. Engaged in investigating new Analytical Methods. Specialty, Commercial Organic Analysis, Expert in Oils, Fats, Soap, etc.

W.

WAINWRIGHT, JOHN HOWARD, PH.B., ... 1882.
Chemist, 402 Washington Street, New York City.

WALKER, H. V., PH.B., ... 1894.
38–40 Clinton Street, Brooklyn, N. Y.

WALKER, ARTHUR LUCIEN, E.M., ... 1883.
Keyser Building, Baltimore, Md., and Lock Box 56, Morristown, N. J.

1883–84, Chemist and Assayer, Old Dominion Copper Co., Globe, Arizona. 1885, Assistant Superintendent of same Co. 1886, Engaged in connection with Iron Metallurgy in New York City. 1887, Mechanical Engineer for Silver King Mining Co., Silver King, Arizona. 1888–93, Superintendent, Old Dominion Copper Co., Globe, Arizona. Also report on all classes of Mining and Metallurgical Property in Arizona. 1893 to date, Consulting Engineer Old Dominion Copper Co., Arizona, and General Manager Baltimore Electric Refining Co.

WALLER, ELWYN, A.B., A.M., E.M., PH.D., . . . 1870.
7 Franklin Place, Morristown, N. J.

WAMPOLD, LEO, PH.B., ... 1888.
204 Monroe Street, Chicago, Ill.

WARD, DELANCY WALTON, PH.B., ... 1888.
Whitestone, N. Y.

WARNER, JOSEPH LOWREY, E.M., ... 1887.
419 Bailey Building, Seattle, Wash.

August, 1887, to August, 1888, Omaha and Grant Smelter, Denver, Assistant Assayer. August, 1888, to July, 1889, Examination of and Reports on Mines in Cœur d'Almes, Idaho, and in O'Kanagan Mining District, Washington. Manager, La Bellevue Mine, same district. July, 1889, to January, 1890, Assistant Superintendent and Amalgamator, Golden Monarch Mine, Oregon. January, 1890–92, Examination and Reports on Mines in Western Washington. Manager, Culver Mining Co. and V. P. Vermilion Iron Co. 1892, Examinations in Cascade Range. 1893, Examinations of Iron Deposits, Island of Texada, British Columbia.

WATSON, FREDERICK MORGAN, E.M., . . . 1885.
Care of S. B. Connor, Esq., Gold Fields Company, Limited, Johannesburg, So. Africa Rep., *via* London.

1885, Assayer and Surveyor, La Maria Mining Co., Mexico. 1886–89, Engineer, Mill Superintendent, Sombrerete Mining Co., Mexico. Concentration and Lixiviation. 1890, Engineer for Peru Exploration Syndicate, Ltd., Peru. 1891 to date, Examining Engineer for Frecheville Bros. Special Experience in Roasting Rebellious Ores. Lixiviation by Russell Process and Superintendent as above.

WATSON, ROLLA BARNUM, E.M., ... 1891.
Park City, Utah, and 403 Sibley Street, Cleveland, Ohio.

Assayer, Candemena, Mexico, 1891. Supt. Erection of Power Plant for Electric Street R. R., Atlanta, Ga., 1892. September, 1893, with Dewey-Walter Refining Co., Marsac Mill, Park City, Utah. December, 1893, to date, Superintendent Dewey-Walter Refining Co.

WEDEKIND, EDWIN HUTTER, PH.B., ... 1889.
Lebanon, Pa.

WEED, WALTER HARVEY, E.M., ... 1883.
U. S. Geological Survey, Washington, D. C., and care S. R. Weed, South Norwalk, Conn.

1883 to date, Geologist on the U. S. Geological Survey. 1883–89, general geology of the Yellowstone National Park, especially of sedimentary rocks, with examinations of the adjacent mining regions. 1890, structural and economic geology of the country north of the Yellowstone Park, with special studies of the coal-fields of Montana. Specialty, economic and stratigraphic geology. Publications: "A Deadly Gas-spring in the Yellowstone National Park."—*Science.* "The Diatom-beds and Marshes of the Yellowstone National Park."—*Bot. Gazette.* "The Formation of Hot Spring Deposits."—Ninth Annual Report of the Director U. S. Geological Survey. "Geysers."—SCHOOL OF MINES QUARTERLY. "Notes on the Coal-Fields of Montana."—SCHOOL OF MINES QUARTERLY. "The Cinnabar and Bozeman Coal-Fields of Montana."—*Bulletin Geological Society of America*, and other papers.

WEEKS, WILLIAM HOLDEN, PH.B., ... 1889.
789 Madison Avenue, New York City.

1889-90, Assistant Chemist New York Chemical Manufacturing Company. April, 1890, to date, Assistant Chemist Health Department, New York City.

WELCH, ALEXANDER MCMILLAN, PH.B. (Arch.), . . 1890.
447 Lexington Avenue, New York City.
1890-91, in architect's office. 1891-93, McKim Fellow, travelling in Europe. 1893 to date, as above.

WELLS, JAMES SIMPSON CHESTER, PH.B., PH.D., . . 1875.
Columbia College, School of Mines, New York City, and 222 Union Street, Hackensack, N. J.
1875-79, Assistant in Quantitative Analysis, School of Mines. Vacation of 1877, spent as Night Superintendent Pennsylvania Lead Works. 1879-93, Instructor in Qualitative Analytical Chemistry, School of Mines.

WERTHEIMER, LEWIS, PH.B., ... 1887.
Western and Bedwell Streets, Allegheny City, Pa., and 316 W. Forty-fifth Street, New York City.

WESTERVELT, WILLIAM Y., E.M., ... 1894.
Ducktown Sulphur, Copper and Iron Co., Isabella, Polk County, Tenn., and 1168 Broadway, New York City.

WHEELER, HERBERT ALLEN, E.M., ... 1880.
Box 340, and 2700 Pine Street, St. Louis, Mo.
During 1880, Assistant Geologist in Utah, on U. S. Geological Survey. During 1881, Assistant Engineer Denver and Rio Grande Western Railroad, in Utah and Colorado, on location and construction. During 1882, Superintendent Vermont Copper Company, Ely, Vermont. From 1883 to 1894, at Washington University, St. Louis; Adjunct Professor of Mining; also Consulting Mining Engineer. Since 1891, Assistant Missouri Geological Survey. 1894, Consulting Mining Engineer.

WHITE, ROBERT DAVIS, C.E., ... 1892.
East River Gas Co., 138 W. Forty-second Street, and 39 E. Seventy-fourth Street, New York City,

WHITE, THEO. G., PH.B., ... 1894.
Geol. Department, Columbia College, and 39 W. Twenty-sixth Street, New York City.
Summer of 1893, Working on the Geology of the Lake Champlain region. Summer of 1894, Traveling and examining mining regions surrounding the Great Lakes in Canada and United States, also researches on the Geology of Mt. Desert Island, Maine. 1894, Post-Graduate Student in Geology.

WHITLOCK, HERBERT PERCY, C.E., ... 1889.
Assistant in Mineralogy, Columbia College, School of Mines, and 449 Park Avenue, New York City.

WIECHMANN, FERDINAND G., PH.B., PH.D., . . . 1881.
Instructor in Chemical Philosophy and Chemical Physics, Columbia College, School of Mines, and 647 West End Avenue, N. Y. City.
Consulting Chemist American Sugar Refining Co., Brooklyn, N. Y.

WIENER, WILLIAM, A.M., PH.B., ... 1891.
Newark High School, and 62½ Nelson Place, Newark, N. J.
1891-92, Chemist to the Hanson, VanWinkle Co., Newark, N. J. 1892-93, Chemicals for Electro-plating, 87 and 89 Mechanic Street, Newark, N. J. 1893, to date, Instructor in Newark High School, and general chemical practice.

WILLIAMS, GRANVILLE WHITTLESEY, E.M., C.E., . . 1879.
333 Genesee Street, Utica, N. Y.

WILLIAMS, JOHN TOWNSEND, E.M., PH.B., . . . 1873.

Architect and Builder, 54 Franklin Street, and 871 Madison Avenue, New York City.

WILLIAMS, WILLIAM FISH, C.E., E.M., ... 1881.

City Land Surveyor, Odd Fellows Bldg. and 241 Pleasant Street, New Bedford, Mass.

1890, while filling the position of Assistant Engineer to A. B. Drake, Civil Engineer, of New Bedford, I accepted the position of Chief Engineer to the Cumberland Lands, Ltd., of Stewart County, Tenn. P. O. address, Dover. 1892, Assistant Manager and Engineer to the same Company; later, Chief of the Dept. of Mining, Construction and Engineering, and also Assistant Manager in the same Company. 1893, resigned, and came to New Bedford. Elected City Land-Surveyor and City Engineer with the old title of City Surveyor to the City of New Bedford.

WILLIS, BAILEY, E.M., C.E., ... 1878.

U. S. Geological Survey, Washington, D. C.

June, 1879, to July, 1881, Special Agent Tenth Census; sampler of iron-ores and student of iron deposits in States east of the Mississippi river. August, 1881, to June, 1884, Geologist in charge of Pacific division of Northern Transcontinental Survey, chiefly engaged in coal explorations in Washington, Oregon and Montana. July, 1884, to February, 1889, Assistant Geologist U. S. Geological Survey, working in Tennessee and North Carolina. March, 1889, to June, 1893, Geologist in charge of Appalachian division, U. S. Geological Survey, directing work and studying geologic problems of the Palæozoic rocks south of Pennsylvania. 1891–93, Editor of Geologic Maps for Folios of the Geologic Atlas of the United States.

WILSON, HERBERT M., C.E., ... 1881.

U. S. Geological Survey, Washington, D. C.

1881–82, Leveller and Transitman, afterwards Chief of Preliminary party, S. & D. R.R., Mexico. 1882–88, Topographer U. S. Geological Survey. 1889–90, Division Engineer, U. S. Irrigation Surveys. 1891, Geographer, U. S. Geological Survey. 1894, Chief Geographer.

WILSON, WILLIAM ALEXANDER, E.M., ... 1882.

University Club, Salt Lake City, Utah.

Assayer for two and a half years. Superintendent of Sampling Mill for two years. Superintendent of 30-Stamp Mill (dry crushing, chloridizing, amalgamating and lixiviating, capacity sixty tons per day) for five years. Specialty, treatment of silver and gold-ores and examining and reporting on mining properties. Superintending of Mining or Milling Operations.

WILTSIE, ERNEST ABRAM, E.M., ... 1885.

General Manager Geldenhuis Est. and Gold Mining Co., Johannesburg, South African Republic.

1885–86, Assistant Chemist Edgar Thomson Steel Works, Braddock, Pa. 1886 to May, 1887, Chemist Colorado Coal and Iron Company, Pueblo, Colo. May, 1887, to August, 1888, Chemist for the Globe Smelting and Refining Company, Denver, Colo. August, 1888, to April, 1890, Assistant Superintendent North Star Mining Company, Grass Valley, Cal. April, 1890–91, Superintendent Menlo Mines, Grass Valley, Cal. January, 1892, Expert work, Nevada Co., Cal. January to August, 1892, with California State Mining Bureau. August, 1892, to January, 1893, Expert work through California. April, 1893, Manager Gold Mines for Barnato Bros., Johannesburg, So. Africa. July 1, 1894, Geldenhuis Est. and Gold Mining Co., Johannesburg, S. A. Rep.

WINDOLPH, ERNEST PAUL, PH.B., ... 1892.
Address unknown.

WITTMACK, CHARLES AUGUSTUS, M.S., PH.B., PH.D., . 1882.
79 West 87th Street, New York City.

WOOLSON, IRA HARVEY, E.M., ... 1885.
Columbia College School of Mines, New York City.

1885–86, Assistant Geological Survey of New Jersey. 1886–87, Assistant Assay Department, School of Mines. 1887–89, Assistant Drawing Department, School of Mines. 1891 to date, Instructor Mechanical Engineering and Drawing, School of Mines.

Y.

YOUNG, EDWARD LEAVITT, E.M., ... 1882.
90 Broadway, and 317 W. Eighty-ninth Street, New York City.

HONORARY MEMBERS.

CHANDLER, CHARLES F., PH.D.
Professor of Chemistry, School of Mines, Columbia College. Address, 51 East Fifty-fourth Street, New York City.

EGLESTON, THOMAS, E.M., PH.D.
Professor of Mineralogy and Metallurgy, School of Mines, Columbia College. Address, 35 West Washington Square, New York City.

MILLER, GEORGE M.
Ringwood, New Jersey.

ROOD, O. N., A.M.
Professor of Physics, Columbia College. Address, Columbia College, New York City.

VAN AMRINGE, J. H., A.M., PH.D.
Professor of Mathematics, School of Mines, Columbia College. Address, 66 West Forty-seventh Street, New York City.

WARE, WILLIAM R., B.S.
Professor of Architecture, School of Mines, Columbia College. Address, 126 East Twenty-eighth Street, New York City.

HONORARY MEMBERS DECEASED.

AGNEW, C. R.,	1888.
BARNARD, F. A. P.,	1889.
NEWBERRY, J. S.,	1892.
PECK, W. G.,	1892.
RUTHERFURD, L. M.,	1892.
TROWBRIDGE, W. P.,	1892.
FISH, HAMILTON,	1893.

LIST No. 3.

Contains the names of Graduates of the School of Mines, not members of the Alumni Association, nor participating in the benefits of such membership. For this reason great uncertainty prevails as to many of the addresses given, which are the best at hand.

It is very desirable that this list should be shortened as far as practicable by the transfer of names from it to the preceding List, No. 2, under the Rules.

(Revised to May, 1895.)

Clayton, William Robert, Ph.B., ... 1890.
Architect, 31 and 32 Rialto Building, Chicago, Ill.
Cloud, Leo George, A.B., S.M., ... 1879.
216 Monmouth Street, Newport, Ky.
Colton, Frederick Gray, Ph.B., ... 1890.
136 Montague Street, Brooklyn, N. Y.
Colt, S. B., Ph.B., ... 1883.
1197 Broad Street, Newark, N. J.
Comstock, Claude Nichols, C.E., ... 1888.
Address unknown.
Constant, Charles Louis, E.M., C E., ... 1877.
32 Park Street, Jersey City, N. J.
Cornwall, George Rockwell, E.M., C.E., ... 1876.
189 Lefferts Place, Brooklyn, N. Y.
Coursen, George Hampton, E.M., C.E, ... 1868.
Address unknown.
Covell, W. S., Ph.B., ... 1893.
42 West Sixty-sixth Street, New York City.
Coykendall, Thomas Cornell, C.E., ... 1890.
Rondout, N. Y.
Cozzens, Harmon, E.M., ... 1885.
Address unknown.
Cristy, Edward Buxton, Ph.B., ... 1891.
Albuquerque, New Mexico.
Cromwell, James William, Jr., Ph.B., ... 1889.
Architect, 29 Brevoort Place, Brooklyn, N. Y.
Crowell, Charles B., Ph.B., ... 1885.
Minneapolis, Minn.
Curtis, Charles Gordon, C.E., ... 1881.
President Curtis Electrical Mfg. Co., Whiton St., Jersey City, N. J.

Davis, William Monroe, E.M., ... 1890.
Syracuse, N. Y.
Del Calvo, Francis, C.E., ... 1884.
Address unknown.
Detwiller, Charles Henry, Ph.B., ... 1885.
Detwiller & Melendy, 97 Nassau Street, New York City, and 56 Danforth Avenue, Jersey City, N. J.
Doolittle, Charles Horace, E.M., ... 1885.
Address unknown.
Downing, Orrien Pinkerton, Ph.B., ... 1878.
116 Battery Street, San Francisco, Cal.
Dunn, Gano Sillick, B.S., E.E., ... 1891.
Elect. Engineer, Crocker-Wheeler Electric Co., Ampere, East Orange, N. J.
Durham, Edward B., M.E., ... 1892.
Mt. Kisko, N. Y.

Eliot, Walter Greame, E.M., C.E., Ph.B., Ph.D., ... 1878.
"University Magazine," 70 South St., and University Club, N. Y. City.
Ellis, A. Van Horn, C.E., ... 1889.
Bartow-on-Sound, N. Y.
Emery H. G., Ph.B., ... 1894.
Nyack, N. J.

Escobar, Francisco, E.M., ... 1889.
842 Wilson Avenue, Cleveland. Ohio.

Fales, William, E.S., E.M., LL.B., ... 1871.
Amoy, China.

Fellows, William K., Ph.B., ... 1894.
7818 Eggleston Avenue, Chicago, Ill.

Fenner, Clarence Norman, M.E., ... 1892.
Paterson, N. J.

Ferguson, George Albert, Ph.B., ... 1890.
138 Wilson Street, Brooklyn, N. Y.

Fisher, Lloyd Wiegand, Ph.B, ... 1890.
109 E. Twenty-eighth St., N. Y. City.

Fitch, Charles Lincoln, E.M., ... 1882.
157 Van Buren Street, Brooklyn, N. Y.

Fitch, Josiah Huntingdon, E.M., ... 1884.
Address unknown.

Fitzgerald, George E., E.M., ... 1884.
El Paso, Texas.

Francke, Robert Otto, C.E., ... 1880.
W. Passburg, Esq., Moscow, Russia.

Frankfield, Emil, C.E., ... 1886.
328 W. Fifty-sixth Street, New York City.

Frisbee, H. D., E.E., ... 1894.
1340 Fulton Street, New York City.

Fuentes, Paul, E.M. . . . . 1894.
321 Hudson Street, Hoboken, N. J.

Gage, Samuel Edson, Ph.B., ... 1887.
Architect, 114 Fifth Avenue, New York City.

Gardner, Watts Denning, C.E., ... 1883.
Board of Health, New York City.

Garrison, Edmund Hoyt, E.M., C.E., ... 1876.
84 Highland Street, Yonkers, N. Y.

Geer, George Jarvis, Jr., E.M., ... 1868.
Merchant, 453 Broome Street, New York City.

Giddings, Edward Everett, E.M., ... 1867.
Merchant, 413 Royal Insurance building, Chicago, Ill.

Gillette, Halbert Powers, M.E., ... 1892.
Ketcham, Idaho.

Goldsmith, Byron Benjamin, Ph.B., ... 1887.
19 East Seventy-fourth St., New York City.

Gould, Edward Ludlow, C.E., ... 1890.
59 Hawthorne Avenue, Yonkers, N. Y.

Greene, Wilkins Updike, Ph.B., ... 1880.
104 Columbia Heights, Brooklyn, N. Y.

Gregory, L. E., ... 1893.
406 Passaic Avenue, Kearney, N. J.

Griffin, S. P., Jr., ... 1884.
449 Park Avenue, New York City.

Griffith, Vincent Colyer, Ph.B., ... 1889.
160 Herkimer Street, Brooklyn, N. Y.

Griggs, Wilfred Elizur, Ph.B., ... 1889.
Architect, Waterbury, Conn.

Haas, Harry Leopold, Ph.B., ... 1878.
Carrère and Haas, 36 Park Place, New York City.
Hamilton, Schuyler, Jr., A.B., A.M., E.M., ... 1876.
Croton-on-Hudson, Westchester Co., N. Y., Architect and Brick Manufacturer.
Hanson, R. C., C.E., ... 1894.
79 Manhattan Avenue, New York City.
Harker, Charles Sumner, E.M., ... 1879.
26 Montgomery Street, San Francisco, Cal.
Harmer, Thomas Hayes, A.B., A.M., E.M., ... 1867.
113 East Twenty-seventh Street, New York City.
Harrison, Newton, E.E., ... 1892.
Elect. Engr., 136 Liberty St., New York City.
Hart, Burnham, C.E., ... 1885.
Ramsay, N. J.
Hart, Charles Henry, C.E., ... 1890.
190 Lenox Avenue, New York City.
Hasegawa, Yothinosuke, E.M., Ph.D., ... 1878.
Mitsu Bishi Sha, No. 11, Awajicho, Nichome Kanda, Tokio, Japan.
Hawkes, Emil MacDougal, A.B., E.M., ... 1885.
267 Fifth Avenue, New York City.
Hay, Arthur, M.E., ... 1892.
821 So. Second St., Springfield, Ill.
Heath, Frederick Milton, E.M., ... 1867.
Potsdam, St. Lawrence County, N. Y.
Heinze, Frederick Augustus, E.M., ... 1889.
General Manager Montana Ore Producing Co., Butte, Montana.
Hemmer, Frederick Adolph, Ph.B., ... 1881.
Box 6, Edgewater, N. J.
Hooper, Louis Mosher, C.E., ... 1880.
Rutherford, N. J.
Holter, Norman Bernard, E.M., ... 1891.
A. M. Holter Hardware Co., Helena, Mont.
Horn, James Thurston, A.B., C.E., ... 1884.
Naval Architect, and 13 E. Fifty-third Street, New York City.
Hornbostel, Henry Frederick, Ph.B., ... 1891.
39 Second Place, Brooklyn, N. Y.
Hoyt, John Sherman, C.E., ... 1890.
934 Fifth Avenue, New York City.
Hoyt, R., C.E., ... 1893.
Katonah, N. Y.
Hudson, Edward Henry, C.E., ... 1890.
Address unknown.
Huntting, Henry Ogden, Ph.B., ... 1887.
Architect, 454 Ceasson Avenue, Brooklyn, N. Y.

Ives, Arthur Stanley, C.E., E.E., ... 1889.
33 Sidney Place, Brooklyn, N. Y.

Jackson, Charles Edward, C.E., ... 1875.
15 Courtland Street, New York City.
Jacobs, H. H., Ph.B., ... 1894.
107 E. Seventy-eighth Street, New York City.
Jarmulowsky, Meyer, Ph.B., ... 1890.
27 Jefferson Street, New York City.

Joffe, Mayer, C.E., ... 1894.
Verona, N. J.
Jenney, Walter Proctor, E.M., Ph.D., ... 1869.
Rapid City, South Dakota.
Johnston, Robert Andrew, C.E., ... 1879.
Attorney and Counsellor, 132 Nassau Street, New York City.
Jones, E. M., C.E., ... 1894.
312 W. Twenty-eighth Street, New York City.
Jones, Thomas John, Met. Eng., ... 1890.
Pulaski City, Va.
Jordao, Jose Nabor Pacheco, C.E., E.M., Ph.B., ... 1877.
Address unknown.
Judd, Charles Breck, E.M., ... 1881.
Westinghouse Building, Pittsburgh, Pa.

Karr, C. P., Ph.B., ... 1878.
1 Union Square, West, New York City.
Keeler, Frederick Sterling, Ph.B., ... 1891.
530 Bouch Avenue, Buffalo, N. Y.
King, Charles, Ph.B., ... 1876.
Railroad contractor, King and Dickinson, Tacoma, Wash.
Kletchka, John Joseph, A.B., C.E., ... 1892.
247 Willis Avenue, New York City.
Knapp, John Augustus, A.B., A.M., E.M., ... 1870.
Chicago and Aurora Smelting Co., Chicago, Ill.
Knox, Charles E., E.E., ... 1892.
Jas. W. Queen & Co., Philadelphia, Pa.
Kohn, Robert David, Ph.B., ... 1890.
4 Rue Honoré Chevalier, Paris, France.
Korn, Louis, Ph.B., ... 1890.
261 Broadway, New York City.

Ledoux, Augustus Damon, Ph.B., ... 1881.
P. O. Box 426, Richmond, Va.
Lee, Henry Charles, C.E., ... 1886.
127 East Twenty-first Street, New York City.
Lichtenstein, Edward Gervaise, Ph.B., ... 1890.
14 W. Seventy-fourth Street, New York City.
Lindsley, Stewart, E.M., ... 1870.
Orange, N. J.
Livingston, Goodhue, Ph.B., ... 1892.
Geo. B. Post, Century Bldg., New York City.
Lord, Nathaniel Wright, E.M., ... 1876.
Professor Mining and Metallurgy, Ohio State University, Columbus, O.
Lowndes, William Shepherd, Ph.B., ... 1890.
42 Sherman Place, Jersey City, N. J.

McDowell, Frederick H., E.M., ... 1872.
66 Cortlandt Street, New York City.
McIlvaine, Alexis Reed, Ph.B., ... 1888.
Architect, 48 Exchange Place, New York City.
McKee, S. H., E.M., ... 1893.
Los Angeles Terminal Railway Co., Los Angeles, Cal.

McKinlay, James Buell, M.E., ... 1892.
108 W. Seventy-ninth Street, New York City.
McKleroy, William Henry, Met. Eng., ... 1890.
Cashier Anniston National Bank, Anniston, Ala.
McNeil, Charles R., Ph.B, ... 1894.
Litchfield, Conn.
Macy, V. E., Ph.B., ... 1893.
18 West Fifty-third Street, New York City.
Maghee, John Holme, A.B., A.M., C.E., ... 1876.
Cayuga Lake Ice Line, Rochester, N. Y., and 29 East Thirty-second Street, New York City.
Mahl, J. Thomas, C.E., ... 1891.
Houston, Texas.
Mann, Horace Borchsenius, Ph.B., ... 1890.
Orange, N. J.
Mapes, Charles Halstead, Ph.B., ... 1889.
60 West Fortieth Street, New York City.
Marsh, Charles Wells, Ph.B., Ph.D., ... 1879.
435 Fifth Avenue, New York City.
Matthews, Charles Thompson, Ph.B., ... 1889.
Architect, Elm Park, Norwalk, Conn.
Matthew, W. D., Ph.B., ... 1893.
St. John, N. B., Canada.
Matsui, Nawokichi, Ph.B., Ph.D., ... 1878.
Agricultural College, Konaba, Tokio, Japan.
Mattison, Joseph Godley, Ph.B.. . . . . 1880.
Real Estate and Insurance Broker, 20 West Fourteenth Street, New York City.
Meikleham, Thomas Mann Randolph, C.E., ... 1890.
Jamaica, Long Island, N. Y.
Meisel, Frederic, Ph.B., ... 1892.
44 Strong Place, Brooklyn, N. Y.
Mesa, Antonio Esteban, C.E., ... 1882.
Address unknown.
Mears, George K., E.E., ... 1894.
Elizabeth, N. J.
Moeller, Rudolph, Ph.B., ... 1887.
336 West Twenty-ninth Street, New York City.
Morgan, L., Ph.B., ... 1888.
47 Fulton Street, New York City.
Morewood, George Barrow, E.M., Ph.D., ... 1878.
156 W. Seventy-sixth St., New York City.
Morewood, Henry Francis, E.M., Ph.D., ... 1876.
Importer, Box 2087, New York City.
Morris, B. W., Jr., Ph.B., ... 1894.
33 W. Forty-second Street, New York City.
Mott, Henry Augustus, Jr., Ph.D., E.M., Ph.D., ... 1873.
Mining Engineer and Analytical Chemist, 155 Broadway, New York City.
Munroe, M., E.E., ... 1894.
Address unknown.
Murray, George, E.M., ... 1874.
235 West Twenty-third Street, New York City.
Murchison, K. M., Jr., Ph.B., ... 1894.
46 W. Fifty-Seventh Street, New York City.

Nambu, Kiugo, E.M., ... 1878.
Nagasaki, Japan.
Nettre, L. R., E.M., ... 1869.
26 Coventry Street. W., London, England.
Newton, T. M., Ph.B., ... 1893.
40 West Seventy-fifth Street, New York City.
Neymann, Percy, Ph.B., ... 1881.
Chemist and Assistant Superintendent, 36 Michigan St., Cleveland, O.
Nichols, Harry Parmelee, E.M., ... 1887.
Hotel St. George, 49 E. Twelfth St., N. Y. City.
Noble, Charles Milton, E.M., ... 1879.
Manager Ruttan Mfg. Co., Anniston, Ala.

Oakes, J. C., Ph.B., ... 1893.
423 West Twenty-first Street, New York City.
Oseranski, Isaac Henry, C.E., ... 1869.
Address unknown.
Owens, Robert Bowie, E.E., ... 1891.
Professor Elect. Engineering, Univ. of Nebraska, Lincoln, Neb.
Oxnard, James Guerrero, Ph.B., ... 1883.
Norfolk, Neb.

Palmer, Cortlandt Edward, E.M., ... 1878.
Colorado Springs, Colo.
Parmly, Chas. Howard, B.S., E.E., ... 1892.
344 W. Twenty-ninth Street, New York City.
Parsons, H. A., C.E., ... 1894.
South Norwalk, Conn.
Parsons, George H., E.M., ... 1868.
Colorado Springs, Colo.
Pazos, Vincent Felix, E.M., ... 1878.
Address unknown.
Pederson, F. M., E.E., ... 1893.
327 W. Thirty-fourth Street, New York City.
Perry, Nelson W., E.M., ... 1878.
Editorial Staff "Electrical World," New York City.
Pfister, Philip Charles, E.M., ... 1875.
Address unknown.
Pierce, Harry Nelson, E.M., ... 1885.
Address unknown.
Platt, Charles Slason, E.M., ... 1868.
Assayer, 21 and 31 Gold St., New York City.
Pomeroy, W. A., E.M., ... 1893.
Oswego, Oregon.
Pope, J. R., Ph.B., ... 1894.
111 E. Twenty-fifth Street, New York City.
Portuondo, Jose, C.E., ... 1890.
San Basilio, Alta 28, Santiago, Cuba.
Post, R. B., Ph.B., ... 1893.
Elizabeth, N. J.
Post, William Stone, Ph.B., ... 1890.
Bernardsville, N. J.

Powers, Cornelius Van Vorst, Ph.B. . . . . 1882.
Address unknown.

Primelles, Jose Alejandro, C.F., ... 1887.
Mercedes 23, Puerto Principe, Cuba.

Prince, A. D., C.E., ... 1893.
30 W. Forty-seventh Street, New York City.

Prince, John L., E.E., ... 1894.
868 Flatbush Avenue, Brooklyn, N. Y.

Proctor, William Ross, E.M., ... 1884.
43 and 45 Sixth Avenue, Pittsburgh, Pa.

Provot, F. A., C.E., ... 1893.
Box 166, Orange Valley, N. J.

Provot, George, Ph.B., ... 1889.
Architect, 24 Highland Terrace, Orange, N. J.

Radford, William Helsham, E.M., ... 1877.
Lydenburgh Gold Mining Co., Limited, Manchester, Eng.

Randolph, Edmund, Ph.B., ... 1883.
E. & C. Randolph, 7 Nassau St., New York City; also Knickerbocker Club.

Raymer, George Sharp, A.B., E.M., ... 1881.
Mine Superintendent, Idaho Springs, Colorado, and 63 Seventh Avenue, Brooklyn, N. Y.

Raymond, Alfred, Ph.B., ... 1891.
123 Henry Street, Brooklyn, N. Y.

Reed, William Bell Stephen, E.M., ... 1879.
Helena, Mont.

Rees, B. F., ... 1874.
Chattanooga, Tenn.

Reese, William W., A.B., E.E., ... 1892.
New Hamburgh, N. Y.

Rennard, John C., E.E., ... 1894.
302 W. Seventy-third Street, New York City.

Reynolds, M. T., A.M., ... 1893.
98 Columbia Street, Albany, N. Y.

Richmond, William Thomas, Ph.B., ... 1881.
68 Thomas Street, New York City.

Riggs, Geo. Washington, Ph.B., ... 1871.
Summit, N. J.

Rittenhouse, Charles T., E.E., ... 1894.
247 W. 138th Street, New York City.

Roberts, Arthur Carr, E.M., ... 1881.
Address unknown.

Roberts, Gracie Sayre, E.M., C.E., ... 1871.
Sewer Bureau, Dept. City Works, Brooklyn, N. Y.

Robertson, Kenneth, E.M., ... 1868.
General Manager West Superior Iron and Steel Co., W. Superior, Wis.

Robertson, Richard Spotswood, Jr., E.M., ... 1871.
Jackson, Minn.

Robinson, F. G., E.E., ... 1893.
Superintendent Amsterdam Street Railway, Amsterdam, N. Y.

Robinson, Henry Alvord, Ph.B., ... 1880.
Lawyer, 150 Broadway, New York City.

Rogers, Charles Louis, E.M., C.E., ... 1877.
823 Broad Street, Chattanooga, Tenn.

Ross, William Coleman, C.E., M.E., ... 1876.
Address unknown.
Rutherford, Francis Morris, E.M., ... 1879.
Assistant Engineer, Maintenance of Way, R. & D. R. R., Richmond, Va.
Rutherford, Lewis Hopkins, E.M., ... 1887.
Franklin, Pa.

Sanders, Wilbur Edgerton, E.M., ... 1885.
Mine Supt., Ewing and Seventh Avenue, Helena, Mont.
Savage, Seward Merrill, C.E., ... 1892.
2260 Pacific Street, Brooklyn, N. Y.
Sawyer, Charles Pike, Ph.B., ... 1881.
Address unknown.
Searle, Charles D., C.E., ... 1894.
32 W. 126th Street, New York City.
Shack, Albert P., E.M., ... 1868.
Address unknown.
Sherman, C. F. G., C.E., ... 1894.
1138 Seventh Street, Boisé City, Idaho.
Shope, Henry Brengle, Ph.B., ... 1885.
19 West Thirty-second Street, New York City.
Skidmore, Samuel Tredwell, A.B., Ph.B., ... 1889.
71 West Fiftieth Street, New York City.
Sloane, Thomas O'Connor, A.B., A.M., E.M., Ph.D., ... 1872.
South Orange, N. J.
Small, Franklin Maurice, Ph.B., ... 1889.
Architect, 199 Second Avenue, New York City.
Smeaton, William Henry, C.E., E.M., ... 1877.
15 Horatio Street, New York City.
Smedberg, Henry Ashton, A.B., C.E., ... 1884.
347 Fifth Avenue, New York City.
Smith, H. A., Ph.B., ... 1893.
460 West Forty-fourth Street, New York City.
Smith, Maxwell, C.E., ... 1880.
Adon Smith, 8 Bridge Street, New York City.
Smyth, Roland Mulville, E.M., C.E., ... 1877.
452 Produce Exchange, New York City. 1879 to date, banker and broker.
Speyers, Clarence Livingston, Ph.B., ... 1884.
Associate Professor Chemistry, Rutgers College, New Brunswick, N. J.
Stallnecht, Frederick, E.M., ... 1868.
Editor, 11 Bond Street, New York City.
Starr, Henry Fowler, Ph.B., ... 1879.
91 Mt. Pleasant Avenue, Newark, N. J.
Steers, James Rich, Ph.B., ... 1890.
10 East Thirty-eighth Street, New York City.
Steinam, J. L., Ph.B., ... 1894.
31 W. Ninety-fifth Street, New York City.
Stevens, Alexander, C.E., ... 1887.
No. 1 Newark St., Hoboken, N. J.
Stewart, Hunter, E.M., ... 1875.
Address unknown.
St. John, Thomas Matthew, Met. Eng., ... 1890.
New York City.

Stoughton, Arthur Alexander, Ph.B., ... 1888.
1665 Washington Avenue, New York City.
Stoughton, Charles William, C.E., ... 1889.
1665 Washington Avenue, New York City.
Stratton, Alex., E.E., ... 1894.
2013 Fifth Avenue, New York City.
Strieby, William, A.M., E.M., ... 1878.
Professor of Metallurgy and Assaying, Colorado College, Colorado Springs, Colo.
Strout, William Allen, Ph.B., ... 1891.
366 Carlton Avenue, Brooklyn, N. Y.
Suydam, John Richard, Jr., E.M., ... 1879.
14 East Forty-first Street, New York City.

Tenville, George F., Ph.B., ... 1894.
40 So. Clentree Street, East Orange, N. J.
Thomas, Franz Charles, Ph.B., ... 1891.
39} Washington Square, New York City.
Thompson, Milton Strong, Ph.B., ... 1875.
Chemist, Newburyport, Mass.
Thompson, S. C., ... 1893.
Grass Valley, Nevada Co., Cal.
Thorne, William Lincoln, Ph.B., ... 1890.
63 High Street, Yonkers, N. Y.
Tilghman, H. A., E.M., ... 1893.
Sausalito, Cal.
Tompkins, J. A., Ph.B., ... 1894.
223 E. Seventeenth Street, New York City.
Totten, George Oakley, Jr., Ph.B., A.M. (1892), ... 1891.
62 North Eleventh Street, Newark, N. J.
Toucey, Donald Butler, LL.B., E.M., ... 1882.
743 Madison Avenue, New York City.
Towart, James, C.E., ... 1892.
Box 296, Peekskill, N. Y.
Trowbridge, Samuel Breck Parkman, A.B., Ph.B., ... 1886.
Architect, 7 East Forty-sixth Street, New York City.
Tucker, Allen, Ph.B., ... 1888.
80 Washington Square, E., New York City.
Tucker, John Henry, Ph.B., Ph.D., ... 1875.
Globe Smelting and Refining Co., Denver, Colo.
Tuttle, W., Ph.B., ... 1893.
520 Sumner Avenue, Newark, N. J.
Tuttle, William W., E.M., ... 1867.
Springfield, Mo.

Van Boskerck, Robert Ward, E.M., ... 1877.
Artist, 58 West Fifty-seventh Street, New York City.
Van Brunt, Arthur Hoffman, Ph.B., ... 1886.
Architect, 54 Wall Street, New York City.
Vanderbilt, W. D., C.E., ... 1894.
44 Monroe Place, Brooklyn, N. Y.
VanIngen, Dudley Arthur, Ph.B., ... 1892.
135 Henry Street, Brooklyn, N. Y.
Van Leunep, David, E.M., ... 1868.
Auburn, Placer County, Cal. Fruit ranch.

Vatable, J. J., Ph.B., ... 1894.
89 Water Street, New York City.

Wainwright, Richard Tighe, C.E., ... 1890.
Rye, N. Y.

Wallace, William J., Ph.B., ... 1886.
Whitestone, N. Y.

Wallbridge, Frederick Kidder, E.M., ... 1884.
37 Ninth Avenue, Brooklyn, N. Y.

Walker, Joseph, Jr., C.E., ... 1880.
112 East Thirty-seventh Street, New York City.

Wanier, Albert George, Ph.D., ... 1882.
Kruscherville, Staten Island, N. Y.

Ward, Norbert Reillieux, E.M., ... 1882.
Morgan Furn. Co., 1180 Broadway, New York City.

Ware, F. B., Ph.B.. . . . . 1894.
1285 Madison Avenue, New York City.

Warren, Charles Peck, Ph.B., A.M. (1892), ... 1890.
286 Clifton Place, Brooklyn, N. Y.

Warren. Lloyd, Ph.B., ... 1891.
520 Fifth Avenue, New York City.

Waterbury, Cornelius Reed, C.L., C.E., LL.B., ... 1877.
Lawyer, 45 Broadway, New York City.

Waters, George Safford, Ph.B., ... 1889.
Architect, Andrews, Waters & Sherwin, 42 W. Forty-third St., N. Y. City.

Webb, Henry Walter, E.M., LL.B., ... 1873.
Third Vice-President, N. Y. C. & H. R. R.R., and 15 West Forty-seventh Street, New York City.

Wels, Paul O., E.M., B.S., ... 1887.
127 East Ninty-first Street, New York City.

Welsh, Howard Farrington, E.M., ... 1890.
Mingo Mountain Coal and Coke Co., Hartranft, Tenn.

Werner, Henry Clay, Ph.B., ... 1892.
120 East Sixty-fifth St., New York City.

Wetmore, Edwin Atwater, E.M., ... 1875.
Iron Merchant, Marquette, Mich.

Wheatley, Joseph Yendes, C.E., ... 1886.
30 S. Ninth Street, Newark, N. J.

White, Wm. Sherf, E.M., ... 1882.
430 Gold St., Brooklyn, N. Y.

Whitman, Edmund Pineo, E.M., ... 1885.
50 Beacon Street, Boston, Mass.

Williams, Frederick Harrison, E.M., ... 1874.
Riverside Iron Works, and 34 Virginia Street, Wheeling, W. Va.

Wilson, Clarence Edgar, Ph.B., ... 1886.
Address unknown.

Windecker, Clifton Nichols, C.E., ... 1892.
33 Sidney Place, Brooklyn, N. Y.

Wood, George E., E.M., Ph.B., ... 1884.
Architect, 63 William Street, New York City.

Wright, Albert Allen, A.M., Ph.B., ... 1875.
Professor of Geology and Natural History, Oberlin College, Oberlin, O.

LIST No. 4.

Contains the names of Members of the Alumni Association classified territorially by residence. Those not members of the Association are not included by reason of the uncertainty as to address of such persons.

(Revised to April, 1895.)

Alabama.—*Birmingham*, A. J. Lamb, C. A. Meissner; *Tuscaloosa*, S. Friedman.

Arizona.—*Congress*, W. F. Staunton; *Harqua Hala*, R. M. Raymond.

California.—*Bodie*, T. H. Leggett; *Los Angeles*, W. F. Brugman, L. C, Easton; *Napa City*, E. Goodwin; *Palo Alto*, L. R. Lenox; *Pasadena*, C. H. Torrey; *San Francisco*, D. E. Mellis, E. C. Van Blarcom; *San Jose*, R. H. Terhune; *Selby*, E. N. Engelhardt; *Stockton*, E. F. Haas.

Colorado.—*Aspen*, A. F. Bardwell, C. W. Miller; *Colorado Springs*, W. E. Newberry; *Denver*, H. V. F. Furman, M. W. Iles, C. F. Lacombe, B. B. Lawrence, G. A. Schroter, T. B. Stearns; *Durango*, E. J. H. Amy; *Glenwood Springs*, W. B. Devereux; *Leadville*, L. S. Noble; *Pueblo*, A. S. Dwight, E. C. Eddy, H. E. Eilers, F. C. Hamilton, M. B. Holt; *State College*, M. C. Ihlseng; *Tellunde*, T. F. Van Wagenen.

Connecticut.—*Collinsville*, W. Hill; *Hartford*, A. L. Levy; *Milford*, C. R. Harte.

Delaware.—*Wilmington*, H. G. Haskell.

District of Columbia.—*Washington*, E. C. Barnard, Carl Barus, J. S. Cox. Jr., E. M. Douglass, A. W. Dow, W. T. Griswold, H. Hollerith, F. W. Tower, W. H. Weed, B. Willis, H. M. Wilson.

Georgia.—*Savannah*, D. B. Falk.

Illinois.—*Carthage*, J. C. Ferris; *Chicago*, E. G. Barratt, P. Le R. Fearn, S. S. Fowler, H. L. Hollis, C. L. Miller, R. Mulford, S. B. Peck, F. B. F. Rhodes, W. H. Van Arsdale, L. Wampold.

Idaho.—*Rocky Bar*, E. C. Koch.

Indiana.—*Indianapolis*, B. J. T. Jeup; *Muncie*, J. R. Marsh.

Indian Territory.—*Hartshorn*, E. Ludlow.

Iowa.—*Davenport*, F. P. Bemis; *Ottumwa*, S. S. Rice.

Kentucky.—*Middlesborough*, H. J. Merwin.

Louisiana.—*New Orleans*, A. L. Black, G. S. Eastwick, E. P. Eastwick.

Maryland.—*Baltimore*, A. L. Walker; *Glencoe*, E. A. McCulloh.

Massachusetts.—*Boston*, Francis Blossom, A. J. Malukoff; *Cambridge*, J. A. Noyes; *New Bedford*, N. Hathaway, W. F. Williams; *Springfield*, L. J. Powers.

Michigan.—*Houghton*, R. M. Edwards, F. McM. Stanton; *Marquette*, R. A. Parker; *Trenton*, E. D. Church; *Vulcan*, W. Kelly.

Minnesota.—*Minneapolis*, W. R. Appleby; *Soudan*, C. B. Crowell.

Missouri.—*Carthage*, A. O. Ihlseng; *De Soto*, O. M. Munroe; *St. Louis*, E. H. Harris, W. B. Potter, E. Starek, A. Thacher, H. A. Wheeler.

Montana.—*Bozeman*, A. M. Ryon, F. W. Traphagen; *Butte*, F. Sands, S. D. Gifford; *Great Falls*, F. Kleptko; *Helena*, W. H. Aldridge, H. M. Cole, P. A. L. Mannheim, J. R. Parks, C. F. Pearis; *Smelter*, A. F. Emrich, F. M. Smith.

Nevada.—*Sutro*, R. Nicols.

New Jersey.—*Bloomfield*, N. Butler, Jr.; *Crawford*, William C. Clark; *Dover*, F. A. Canfield; *Englewood*, W. W. Burritt; *High Bridge*, C. Le Boutillier; *Jersey City*, W. F. Downs, P. C. McIlhiney, R. H.

Vondy; *Mamaroneck*, F. P. Smith; *Maurer*, G. B. Lee; *Morristown*, J. R. Brinley, J. P. Pennington; *Newark*, H. G. Atha, C. A. Colton. C. E. Graff. A. W. Jenk, F. W. Kinsey, F. E. Pierce, E. Merz, H. M. Murphy, G. C. Stone, E. G. Tuttle, F. Vanderpoel, E. Waller, W. Wiener; *New Brunswick*, A. H. Chester, W. D. Horne; *Orange*, R. K. Mosley; *Passaic*, E. W. Guiterman; *Perth Amboy*, D. F. Haasis, E. H. Messiter; *Plainfield*, F. A. Cokefair, C. Bullman; *Princeton*, H. B. Cornwall; *South Orange*, E. D. Self; *Trenton*, J. H. Janeway, F. E. Pierce.

New York.—*Albany*, F. J. H. Merrill; *Amagansett*, R. P. Miller; *Brooklyn*, R. L. Allen, P. T. Austen, F. R. Bartlett, G. W. Behrman, G. Berry, F. Blossom, D. D. Book, G. H. Casamajor, J. S. Cox, E. P. Clark, H. R. Connell, J. T. Corcoran, J. A. Deghnée, F. D. Dodge, W. L. Dusenberry, L. G. Engel, E. P. Folger, A. D. Granger, S. A. Goldschmidt, W. A. Herckenrath, J. M. Hewlett, B. C. Hinman, E. D. Hurlburt, F. S. Hyde, W. D. Jones, J. S. Langthorn, F. Lyman, W. M. Meserole, J. Middleton. J. Nesmith, T. S. Perkins, A. J. Provost, C. B. Rowland, G. Rowland, R. Seldver, W. W. Share, E. Skinner, G. C. Southard, G. A. Tibbals, S. G. Tibbals, W. L. Tyler, E. Van Dyck, G. J. Volckening, E. R. Von Nardroff, H. V. Walker; *Buffalo*, E. L. Ingram; *Cazenovia*, H. Burden, 2d; *Clifton*, F. R. Lord; *Clinton*, C. H. Smyth; *Flushing*, M. T. Bogert; *Laurel Hill*, W. C. Ferguson; *Locust Valley*, L. H. Vaile; *Mamaroneck*, F. P. Smith; *New Brighton*, A. Hollick; *New Rochelle*, L. P. De Luze; *New York City*, F. E. Agramonte, S. W. Andrews, L. A. Ansbacher, A. Anthony, S. W. Balch, W. M. Baldwin, J. H. Banks, L, H. Barnett, G. S. Baxter, A. L. Beebe, W. L. Benedict, F. P. Benjamin, M. Benjamin, W. G. Berry, J. R. Bien, A Black, E. M. Blake, O. Bodelsen, W. Boecklin, Jr., R. E. Booræm, R. C. Boyd, S. R. Bradley, N. L. Britton, H. D. Brewster, F. X. Brosnan, F. G. Brown, W. Bryce, C. R. Buckley, A. L. Burns, E. R. Bush, N. Butler, W. P. Butler, L. B. Cady, A. Calman, E. P. Casey, J. P. Carson, J. B. Cauldwell, C. F. Chandler, J. P. Channing, J. A. Church, h, G. H. Clark, C. E. Colby, S. B. Colt, G. B. Cornell, H. C. Cornwall, J. C. Cox, F. B. Crocker, A. R. Cushman, H. G. Darwin, C. H. Davis, J. W. Davis, J. A. Deghuee, A. F. Delafield, W. A. Dodsworth, C. F. Dolan, H. E. Donnelly, J. S. Douglas, S. B. Downes, D. LeR. Dresser, I. W. Drummond, E. K. Dunham, B. H. Dutcher, W. G. Eberhardt, T. Egleston, A. H. Elliott, W. Elliott, G. E. Fahys, C. F. Ferrer, H. Feuchtwanger, W. Fisher, F. W. Floyd, R. G. Foster, A. E. Foyé, J. W. Frank, W. H. Freedman, S. A. Goldschmidt, E. B. Gosling, L. P. Gratacap, J. L. Greenleaf, S. P. Griffin, L. N. Gross, E. Gudeman, E. W. Guiterman, L. F. Haffen, A. W. Hale, R. W. Hall, A. P. Hallock, A W. Hankinson, R. C. Hanson, G. E. Harding, O. B. Hébert, A. M. Heinsheimer, H. H. Hendricks, R. W. Hildreth, W. E. Hildreth, F. N. Holbrook, E. H. Holden, W. A. Hooker, F. F. Hunt, F. R. Hutton, O. Jackson, D. M. Jacobs, S. J. Jacobs, C. H. Joüet, C. P. Karr, J. C. Kastner, J. F. Kemp, H. S. Kissam, E. C. Koch, J. J. Koen, W. B. Kunhardt, J. Lahey, R. Lahey, D. G.

Leary, G. Leary, E. J. Lederle, A. R. Ledoux, E. W. Libaire, A. Liebmann, W. P. Little, A. R. Livingston, E. G. Love, L. McI. Luquer, T. T. P. Luquer, G. Lusk, C. F. McKenna, R. A. McKim, J. Maclay, H. T. MacKaye, A. S. Mahony, C.G. Massa, L. F. Massa, R. E. Mayer, C. S. McLoughlin, H. C. Mannheim, L. Marie, E. W. Martin, L. F. Massa, J. H. Merritt, H. H. B. Meyer, E. H. Miller, J. T. Monell, M. R. Montenegro, M. L. Mora, D. E. Moran, W. F. Morgan, G. W. Morris, R. K. Mosley, A. J. Moses, H. S. Munroe, C. E. Munsell, A. H. Napier, K. Neftel, W. Newbrough, E. L. Newhouse, A. C. Nye, M. J. O'Connor, T. D. O'Connor, E. E. Olcott, Max Osterberg, F. N. Owen, A. McC. Parker, H. C. Parker, C. F. Parraga, Henry Parsons, W. B. Parsons, C. Q. Payne, Robert Peele, Jr., C. E. Pellew, J. P. Pennington W. Pistor, L. Pitkin, H. H. Porter, Jr., A. S. Post, A. V. Z. Post, W. E. Preston, J. C. F. Randolph, J. F. Randolph, R. Raynor, S. A. Reed, J. K. Rees, G. Renault, J. M. Rich, P. de P. Ricketts, T. W. Ridsdale, H. Ries, F. Roeser, O. L. Rogers, R. G. Rood, A. Rosenthal, P. Rupp, F. Ruttman, E. E. Sage, F. A. Schermerhorn, W. J. Schiefflein, J. L. Schroeder, C. H. Schumann, J. G. Seligman, F. D. Sherman, H. T. Shriver, F. M. Simonds, A. Smith, L. Smith, W. A. Smith, W. F. Smith, T. E. Snook, A. N. Spooner, J. A. Staunton, J. Struthers, W. H. Stuart, G. A. Suter. J. B. Taylor, H. C. Thompson, W. H. Titus, G. R. Tuska, A. H. Van Sinderin, E. Van Volkenburgh, H. T. Vulte, J. H. Wainwright, W. H. Weeks, H. McM. Welsh, J. S. C. Wells, William Y. Westervelt, R. D. White, T. G. White, H. P. Whitlock, F. G. Wiechmann, J. T. Williams, C. A. Wittmack, I. H. Woolson, E. L. Young; *Niagara Falls*, E. Z. Burns, W. S. Humbert; *Northport*, W. H. Ingersoll; *Ontario*, E. M. Parrot; *Poughkeepsie*, A. E. Tower; *Rochester*, T. Nolan; *Sing Sing*, W. S. Page; *Skaneateles*, F. M. Thomas; *Spuyten Duyvil*, E. M. Johnson, G. H. Johnson, I. B. Johnson, L. B. Longacre; *Staten Island*, G. F. D. Trask; *Syracuse*, H. B. Bellinger; *Tarrytown*, F. N. Holbrook; *Ticonderoga*, F. C. Hooper; *Tuxedo Park*, E. N. Van Cortlandt; *Utica*, G. W. Williams; *Westchester*, T. H. Harrington; *White Plains*, R. E. Slade; *Whitestone*, W. J. Wallace, D. W. Ward; *Yonkers*, S. W. Balch, W. D. Horne.

North Carolina.—*Charlotte*, S. W. Cramer, G. B. Hanna, F. Powell; *Wilmington*, F. S. Clark.

Ohio.—*Cincinnati*, C. B. Going; *Cleveland*, R. F. Jopling, R. B. Watson; *Ivorydale*, J. P. Porter; *Marietta*, C. G. Slack; *Sandusky*, S. B. Newburg.

Pennsylvania.—*Allegheny*, G. H. Singer, L. Wertheimer; *Ambler*, E. Luttgen; *South Bethlehem*, A. L. Colby, *Braddock*, E. Clark; *Chambersburg*, T. J. Brereton; *Lebanon*, E. H. Wedekind; *McKeesport*, T. Tonnelé, T. M. Hopke; *New Boston*, J. E. Jones; *New Castle*, E. L. Kurtz; *Osceola Mills*, G. McC. H. Good; *Philadelphia*, E. A. Congdon, S. M. Lillie; A. C. Munoz, Del Monte, Charles Piez; *Pittsburgh*, R. G. G. Moldehnke, G. S. Page, C. A. Painter, G. E. Painter, G. Singer, Jr.; *Wilkesbarre*, R. V. A. Norris; *Wyncote*, E. Luttgen.

South Carolina.—*Charleston*, P. E. Chazal.
Tennessee.—*Tracy City*, J. J. Ormsbee.
Texas.—*Eagle Pass*, W. Hollis; *Shafter*, W. S. Noyes.
Utah.—*Jensen*, A. G. Johnson; *Sandy*, L. H. Norton; *Salt Lake City* H. W. Leavens, T. S. Mathis, W. A. Wilson.
West Virginia.—*Franklin*, T. W. Osterheld.
Wisconsin.—*Hurley*, G. H. Abeel.
Wyoming.—*Rawlings*, C. E. Blydenburgh.
Washington.—*Everett*, W. C. Butler, G. Müller; *Tacoma*, G. F. Milliken; *Seattle*, J. L. Warner.

OUT OF THE UNITED STATES.

AFRICA.

South Africa Republic.—*Johannesburg*, F. M. Watern, E. A. Wiltsie.

AUSTRALIA.

New South Wales.—Randolph Adams.

EUROPE.

Italy.—*Rome*, S. J. Temple.

GREAT BRITAIN.

London.—C. M. Rolker.

NORTH AMERICA.

Canada.—*Golden*, S. S. Fowler; *Montreal*, C. E. Gudewill; *Quebec*, R. D. Rhodes.

SOUTH AMERICA.

Brazil.—*Rio de Janeiro*, John Gordon.

Republic of Colombia.—*Medellin*, C. C. Restrepo; *Tumaco*, H. D. Conant.

CENTRAL AMERICA.

Cuba.—*Cardenas*, D. L. Clark; *Cienfuegos*, A. C. Fowler; *Matanzas*, Y. Y. Polledo.

Guatemala.—*Quezaltenang*, J. F. Hawley.

Honduras.—*Tegucigalpa*, E. C. Fiallos.

Mexico.—*Chihuahua*, T. S. Austin; *City of Mexico*, V. M. Braschi; *Catalina Durango*, E. L. Dufourcq, H. Garlichs; *Corhuila*, Gomez Farias, Theo. Osterheld; *Monterey*, A. F. Schneider; *Sinaloa*, A. E. Swain; *Sierra Mojada*, E. Howe; *Tapachula Chiopas*, J. A. Navarro; *Concepcion del Oro*, A. W. Lilliendahl, F. A. Lilliendahl; *Hidalgo*, E. C. Van Blarcom; *Pachuca*, George T. Reckhart.

CONSTITUTION

OF THE

ASSOCIATION OF THE ALUMNI

OF THE

SCHOOL OF MINES OF COLUMBIA COLLEGE

INCORPORATED MAY, 1886.

ARTICLE I.

NAME.

THE name of this Association is "The Association of the Alumni of the School of Mines of Columbia College."

ARTICLE II.

OBJECT.

The object of this Association is to promote the professional welfare of its members, and to strengthen the bonds of professional and social fellowship among the Alumni of the School of Mines.

ARTICLE III.

MEMBERS.

SECTION 1. The membership in this Association shall be: I. Active. II. Associate. III. Honorary.

SEC. 2. All graduates of the School of Mines are eligible to active membership in this Association.

SEC. 3. Persons who have completed any of the special or graduate courses of the School of Mines are eligible to associate membership in this Association.

SEC. 4. Persons eminent in science who are or have been connected with the School of Mines are eligible to honorary membership in this Association.

SEC. 5. All members shall be elected by the Association upon proposal by the Board of Managers.

SEC. 6. Honorary and associate members shall have all the privileges of active members, except those of voting and holding office.

ARTICLE IV.

DUES.

SEC. 1. The annual dues of active and associate members of this Association shall be three dollars, payable in advance on the first day of October in each year. Honorary members shall not be required to pay dues.

SEC. 2. Any member not in arrears may become a life member, and be relieved from further payment of annual dues by the payment, at any one time, of fifty dollars.

SEC. 3. Members one year in arrears may, after due notification, be dropped from the roll, by vote of the Board of Managers, and shall then forfeit their rights and privileges in the Association until all arrears are paid, or until reinstated by the Board.

SEC. 4. Only those members not in arrears shall be entitled to vote or hold office.

ARTICLE V.

OFFICERS AND MANAGERS.

SEC. 1. The officers of the Association shall be a President, a Vice-President, a Treasurer, and a Secretary. These officers and eight managers, to be elected as hereinafter provided, shall constitute the Board of Managers.

SEC. 2. The President, Vice-President, Treasurer and Secretary shall hold office for one year, and are eligible for re-election. The Managers shall hold office for two years, and are not eligible for re-election until one year after the expiration of their terms.

ARTICLE VI.

ELECTION OF OFFICERS AND MANAGERS.

SEC. 1. Before the last day of June of each year the President shall appoint a committee of five active members to nominate for election by the Association for the ensuing year a President, a Vice-President, a Treasurer, a Secretary and four Managers.

SEC. 2. The Nominating Committee must send in the nominations to the Secretary not later than October 15th of each year,

and such nominations shall be distributed at once to the active members in the form of letter ballots, which must be signed and forwarded to the Secretary, and opened and counted by tellers at the annual meeting of the Association.

SEC. 3. The officers and managers must be residents of New York city or vicinity, and the four managers shall be selected, one from each of the four groups into which the Board of Managers shall, at its first meeting in each year, divide in chronological order the classes which have graduated from the School of Mines.

ARTICLE VII.

THE BOARD OF MANAGERS.

SEC. 1. The Board of Managers shall have the management of the affairs, funds, and property of the Association, and it shall be the duty of the Board to see that the purposes of the Association are carried out according to its Constitution and By-Laws.

SEC. 2. The Board of Managers shall hold at least four regular meetings during each year, namely, in the months of January, May, October, and December. Other meetings shall be called by the President as may be required.

SEC. 3. The Board shall have power to fill any vacancy in its body by the election of an active member of the Association from the group in which such vacancy occurs.

SEC. 4. A quorum shall consist of a majority of the whole Board.

ARTICLE VIII.

PRESIDENT.

It shall be the duty of the President to call and preside at all meetings of the Board of Managers and of the Association; to appoint such standing and other committees of the Association as may be found necessary or convenient for the conduct of its work, and to perform such other duties as may devolve upon him by virtue of his office.

ARTICLE IX.

TREASURER.

It shall be the duty of the Treasurer to collect and have custody of all moneys and pay all bills of the Association, but no indebtedness shall be incurred unless approved by the Board of Managers. No bill shall be paid unless previously endorsed by

the Secretary. The Treasurer shall present to the Board of Managers a written report upon the financial condition of the Association at the annual meeting in December. His accounts shall be audited by a committee of the Association appointed at the annual meeting.

ARTICLE X.

SECRETARY.

It shall be the duty of the Secretary to issue notices for all meetings of the Board of Managers and of the Association, to keep minutes of all meetings, to record the names, addresses, and professional occupations of the members, and to perform such other duties as may be assigned to him by the Board of Managers.

ARTICLE XI.

DELEGATES TO UNIVERSITY ALUMNI COUNCIL.

This Association shall be represented in the University Alumni Council of Columbia College by delegates appointed by the Board of Managers, under such conditions and in such manner as the said board shall prescribe.

ARTICLE XII.

MEETINGS.

SEC. 1. The annual meeting of the Association shall be held in the last week of December in each year, unless otherwise ordered by the Board of Managers.

SEC. 2. Regular meetings of the Association for social intercourse, or for the discussion of subjects of general or of professional interest, shall be held in the city of New York at such time and place as may be directed by the Board of Managers.

SEC. 3. Upon the written request of not less than ten active members, the President shall call a special meeting of the Association, which request, as also the notice of any special meeting, shall state the object for which the meeting is called.

SEC. 4. A quorum shall consist of thirty active members of the Association.

ARTICLE XIII.

SUSPENSION OR EXPULSION.

Any member of the Association may be suspended or expelled for misconduct in his relations to this Association or in his profes-

sion on proof thereof in such manner as may be prescribed hereafter by By-laws.

ARTICLE XIV.

All interest in the property of the Association of persons resigning or otherwise ceasing to be members shall vest in the Association.

ARTICLE XV.

AMENDMENTS.

Any amendment to the Constitution must first be submitted in writing to the Board of Managers, and must be approved by a vote of two-thirds of the whole Board before presentation to the Association. Due notice of any proposed amendment shall be sent by the Board of Managers to every active member of the Association at least one month previous to the meeting at which such amendment is to be voted upon. A three-fourths vote of the members voting, in person or by letter ballot, shall be necessary for the adoption of such proposed amendment.

BY-LAWS.

I. Unless otherwise directed the Order of Business at any meeting of the Association and its Board of Managers shall be as follows:

1. Reading of minutes of preceding meetings and action thereupon.
2. Report of the Board of Managers.
3. Reports of officers.
4. Reports of standing committees.
5. Reports of special committees.
6. Elections and announcement of elections.
7. Unfinished business.
8. New business.
9. Appointment of committees.
10. Adjournment.

II. The absence of any member of the Board of Managers from two consecutive meetings of the same, of which he shall have been regularly notified, shall be considered as a resignation on the part of such member, unless the Board shall excuse such absence. The vacancy thus created shall be filled as provided for in the Constitution.

III. The Standing Committees of the Board of Managers shall be as follows:

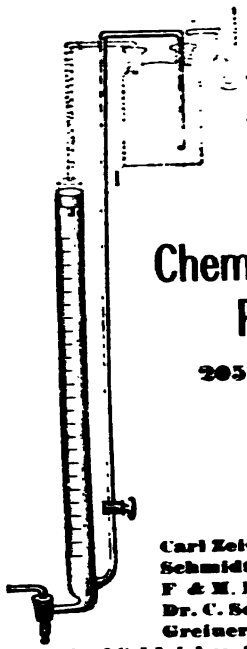
1. On School of Mines Quarterly.
2. On Badges.
3. On Meetings of the Association.
4. Of Conference with the Columbia College Alumni Association, and such other Committees as may be necessary.

All such committees shall, at the expiration of their terms of office, present written reports to the Board of Managers.

IV. The official organ of this Association shall be the SCHOOL OF MINES' QUARTERLY, which will be furnished to all active and associate members.

V. The Standing Committee on Meetings shall arrange for regular meetings of the Association in October and March of each year unless otherwise ordered by the Board of Managers.

VI. These By-Laws may be amended at any regular meeting of the Association, but only by a vote of two-thirds of those present, and provided that ten days' notice in writing of the proposed amendment shall have been given to the Board of Managers, and also that notice of the same shall have been given by the Secretary in the call for the meeting.



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